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# **C O S Y M A**

## **Modelling of Economic Consequences**

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## **Abstract**

One of the main objectives of the MARIA (Methods for Assessing the Radiological Impact of Accidents) programme initiated by the Commission of the European Communities has been to develop a computer program system for assessing the off-site consequences of accidental releases of radioactive material to the atmosphere.

This program system, called COSYMA (COde SYstem from MAria) includes an ECONOMICS module for assessing the off-site economic consequences of the accidents mentioned above. The aim of this module is to convert many of the various consequences caused by an accident into the common framework of economic costs; this allows different effects to be expressed in the same terms and thus to make these effects comparable.

This report is a detailed description of the ECONOMICS module in COSYMA; it contains all necessary and, in addition, much background information for users of COSYMA who wish to understand this module before making their own computer runs. This description refers to the 91/1 version of the ECONOMICS module included in the COSYMA program system, i.e. the version that was issued by late 1991.

## **COSYMA: Modellierung von volkswirtschaftlichen Auswirkungen**

Eines der wesentlichen Ziele des von der Kommission der Europäischen Gemeinschaften initiierten Programms MARIA ("Methods for Assessing the Radiological Impact of Accidents") war, ein Computer-Programmsystem zu entwickeln, um bei einem Unfall die Auswirkungen von Freisetzungen von radioaktivem Material in die Atmosphäre in der Umgebung einer kerntechnischen Anlage abzuschätzen.

Dieses Programmsystem, COSYMA ("COde SYstem from MAria") genannt, enthält einen ECONOMICS-Modul, der es ermöglicht, die volkswirtschaftlichen Auswirkungen von Unfallabläufen der oben genannten Art abzuschätzen. Mit diesem Modul lassen sich verschiedenartige Unfallauswirkungen in volkswirtschaftliche Kosten umrechnen; auf diese Weise können unterschiedliche Effekte in gleichen Einheiten ausgedrückt und damit vergleichbar gemacht werden.

Dieser Bericht ist eine detaillierte Beschreibung des ECONOMICS-Modul in COSYMA; er enthält alle notwendigen und darüber hinaus eine ganze Menge Hintergrund-Informationen für den Benutzer von COSYMA, der diesen Modul verstehen möchte, bevor er eigene Computerläufe durchführt. Die Beschreibung bezieht sich auf die Version 91/1, d.h. die Version des ECONOMICS-Modul, die Ende 1991 im Rahmen des Programmsystems COSYMA herausgegeben wurde.

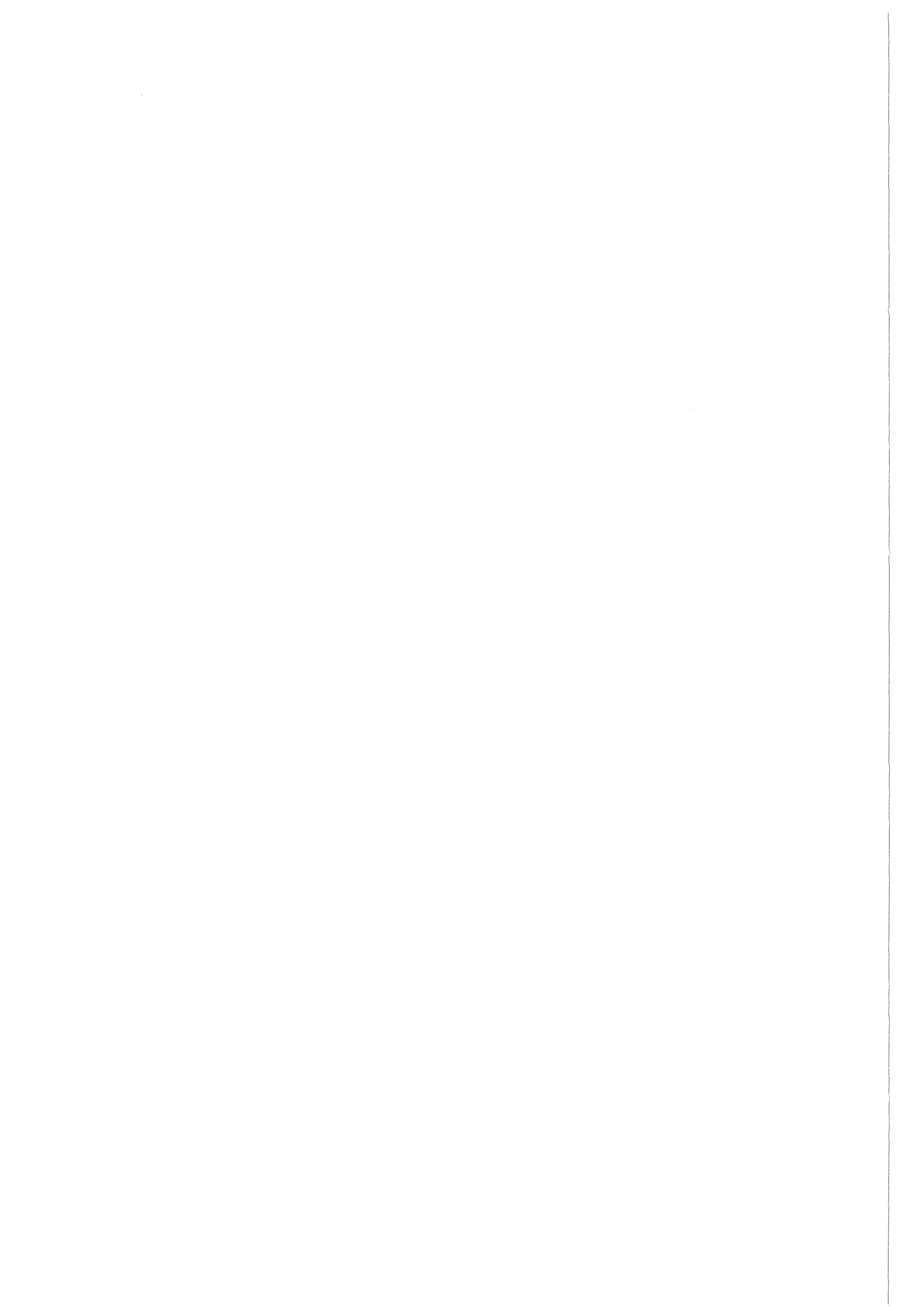
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## 1. Introduction

In 1982, the Commission of the European Communities (CEC) initiated the **MARIA (Methods for Assessing the Radiological Impact of Accidents)** programme with the aim to review and build on the nuclear accident consequence assessment methods in use within the European Community. One of the main objectives of the MARIA programme has been to develop a computer program system for assessing the off-site consequences of accidental releases of radioactive material to the atmosphere. This new program system, called **COSYMA (COde SYstem MARIA)** /1/, was developed jointly by the Kernforschungszentrum Karlsruhe (KfK), FRG, and the National Radiological Protection Board (NRPB), UK.

COSYMA includes an **ECONOMICS** module for assessing the off-site **economic consequences** of an accident in which radioactive material is released to the atmosphere. The model philosophy incorporated into this module is based on a new model called **COCO-1 (Cost Of Consequences Offsite)** that was developed within the framework of collaboration between NRPB and KfK in 1988/89 /2/. The aim of the **ECONOMICS** module in COSYMA is to convert many of the various consequences caused by an accident into the common framework of economic costs; this allows different effects to be expressed in the same terms and thus to make these effects comparable.

This report is a detailed description of the **ECONOMICS** module in COSYMA. It is much more comprehensive than the respective sections of the COSYMA User Guide /3/ (which concentrate mainly on the user input data), and contains all necessary and, in addition, much background information for users who wish to understand this module before making their own computer runs. This description refers to the version **91/1** of the **ECONOMICS** module included in the COSYMA program system, i.e. the version that was issued in late 1991.

In Chapter 2. the basic calculational procedure applied in the module will be described in qualitative terms in order to give an overview and to explain the background of the cost calculations.

A detailed description of the module in quantitative terms will be presented in Chapter 3.. It is recommended to those who want to become familiar with the details of the coding.

Chapter 4. contains all user input parameters that are necessary in the cost calculations, as well as background information - if necessary - for the derivation of the default values assigned to the parameters.

Finally, in Chapter 5. the output of the **ECONOMICS** module will be described together with an example of an output from a run of the module.



## 2. General Modelling Aspects

In this chapter the basic calculational procedure applied in the ECONOMICS module will be described in qualitative terms in order to give an overview and to explain the background (i.e. the model philosophy) of the cost calculations. A detailed description in quantitative terms will be presented in Chapter 3., and the user of the code who wants to become familiar with the details of the coding is referred to both chapters for alternate reading.

### 2.1 *Some Introductory Remarks on Cost Calculations*

An accident in a nuclear facility leading to releases of radioactive material into the environment may cause a large variety of consequences at various levels. At first, there are consequences that can be classified as **physical** or **tangible**; consequences of this kind can be quantified rather easily - at least from their basic approach - and thus normally are modelled in the computer codes for widely used accident consequence assessments, such as in COSYMA. By this level of modelling, the primary consequences, namely radiation-induced health effects (non-fatal and fatal) in the population, as well as secondary consequences resulting from countermeasures taken to reduce the number of radiation-induced health effects are treated. These countermeasures include e.g. the evacuation or relocation of the population from areas with too high levels of radiation exposure, or the decontamination of land and buildings, or restrictions on the production of agricultural products in contaminated areas and on the distribution of contaminated food.

In principle, it is possible to convert these different kinds of physical consequences of a nuclear accident into the common framework of **economic costs**; the advantage of this procedure is that different effects are expressed in the same unit and thus are easy to compare. This conversion is carried out in the ECONOMICS module of the COSYMA program package, and the methodology and limitations of such a procedure will be described here.

However, there is a second level of consequences that can be classified, to contrast with the first, as **non-physical** or **non-tangible**. These consequences may include psychological, human, social or political consequences, such as suffering from anxiety, sorrow or pain due to illness, death or loss of living or working conditions, the loss of cultural goods (beyond monetary values), the destruction of established social structures, the diminishing reputation of a nation in the world, etc..

In principle, it may also be possible, although much more difficult, to convert these non-physical consequences into economic costs. But there are two essential reasons why this has not been done in the ECONOMICS module: The first reason is that non-physical

consequences cannot - or at least cannot immediately - be quantified. But even if it were possible to express these types of consequences quantitatively - and this is the second reason - the "transfer factors" for conversion into monetary units would be largely determined by personal, subjective judgements so that the results would have to be regarded as rather questionable.

Another basic restriction of the ECONOMICS model has to be indicated here: the assessment of economic costs is being performed within the framework of COSYMA. This means that only such consequences can be expressed as costs that have been quantified before in other modules. COSYMA has been designed as an off-site consequence model, and, therefore, only consequences outside the fence of a nuclear facility are considered. All measures taken within the plant area to repair a damaged plant after an accident or to bring damaged parts of the plant into a safe state (this had been an essential undertaking after the Chernobyl accident in 1986) are not considered in COSYMA and, therefore, cannot be converted into economic costs.

Finally, it is necessary to explain the term "costs" as used in the ECONOMICS module. "Costs", "economic costs" and "economic consequences" are used as synonyms. This should indicate that "costs" are not used here in their strict economic meaning which is defined as the valued consumption of economic goods and services, but in a much broader sense that include the total **benefit lost** due to the accident. This lost benefit can be measured by the amount of money that would be necessary to bring the affected area (including the individuals concerned) into the state prevailing before the accident. In this connection, it is irrelevant whether a flow of money really would occur or not - it is simply a method of measuring the consequences of an accident in monetary units.

## **2.2 General Structure of the COSYMA Code System**

It is evident that the ECONOMICS module must fit the general structure of the COSYMA program package in order to be consistent with all other modules and the interfaces for the transfer of data. A detailed description of COSYMA is given in /1/ and /3/, see also publications on COSYMA in /4/, and the reader is referred to these publications for more details. However, to enable the reader to better understand the details of the ECONOMICS module, some major features of the COSYMA structure will be discussed below:

The COSYMA program system is split into the following three subsystems:

- subsystem **NE**, covering the **N**ear range and **E**arly countermeasures and effects,
- subsystem **NL**, covering the **N**ear range and **L**ate countermeasures and effects,
- subsystem **FL**, covering the **F**ar range and **L**ate countermeasures and effects.

The **near range** covers an area in which reliable results will be obtained up to a radius of several tens of kilometres (the default value of the maximum radius is 100 km). On the other hand, the **far range** area provides reliable results starting from a radius of several tens of kilometres; the default value of the maximum radius is on the order of 2000 km. These dimensions are important to the user of the ECONOMICS module, particularly in the case of the subsystem FL of the code. Whereas in the subsystems NE and NL, numerical values of unit costs may normally be derived from **national** statistical data of the country in which sites are located, it may be necessary in the subsystem FL to use cost values which are representative of **European** dimensions.

Subsystems NE and FL can be operated independently of the others, whereas subsystem NL may need information from subsystem NE. Within the various subsystems of COSYMA the same loop structure is applied in each module. The outermost loop refers to different nuclear sites (NS) - if site-dependent calculations are performed - and the next inner loop to different weather sequences (L). Within the loop of weather sequences, calculations for each case (L,NS) are based on a polar coordinate grid system ( $r,\phi$ -grid) with the centre point at the location of the nuclear site.

The total number of cases  $LMAX \cdot NSTMAX$  treated in each run form the basis of the **probabilistic** accident consequence analysis, the results of which are treated in special evaluation programs. In the same way, the ECONOMICS module is split into two major parts: an ECONOM module in which cost calculations are performed for each case (L,NS), and an EVAECO module in which the results calculated in ECONOM are evaluated according to standard procedures that are applied within the whole COSYMA system.

The following health effects and countermeasures may be treated in the corresponding subsystems NE, NL, FL of COSYMA, and the results calculated in preceding modules may be used as a basis for the cost calculations in the ECONOMICS module:

- subsystem NE:
  - evacuation,
  - early health effects.
- subsystem NL:
  - sheltering (only if not followed by evacuation or relocation),
  - relocation (including evacuation),
  - decontamination,
  - food bans,
  - early health effects (only for cost calculations, costs are calculated in the same way as in the subsystem NE),
  - late health effects.
- subsystem FL:
  - relocation,
  - decontamination,



- food bans,
- late health effects.

### **2.3 Input for Cost Calculations**

The principal calculational method of converting an impact of an accident into monetary units is rather simple, being of the form:

$$\text{COST} = \text{QUANT} \cdot \text{UCOST} \cdot \text{FACTOR}$$

In this equation, COST stands for the "cost category" to be calculated, QUANT stands for "quantity" and characterises the impact of the measure that has to be expressed in monetary units, e.g. the number of people relocated, or the area that has to be decontaminated, or the number of health effects. This first type of information will be provided by preceding COSYMA modules, the respective data are stored on data files for reuse. This information may either be of an integral, grid-independent type or refer to each grid element of the  $r, \phi$ -grid. This means that the cost calculations may be performed either on an average, grid-independent level, or on a grid element by grid element basis.

There is a second type of input information to be used which is expressed here by UCOST and FACTOR. UCOST means the specific "unit costs" that correspond to QUANT, and FACTOR stands for any necessary additional calculation effort, e.g. if a time-span has to be considered or if a capital value has to be depreciated or simply if costs have to be discounted.

These economic input data have to be provided directly by the user (see Chapter 4.), and they are treated in COSYMA on the basis of default values and read in within a special input module called INDAT.

For some special options a third type of economic input data are needed: data sets with information on a grid element by grid element basis. This type of information is needed, if e.g. cost calculations will be performed on the basis of economic regions or if a land-use grid will be used. Data sets of this type have to be provided separately for use in the ECONOMICS module.

The procedure to provide economic input data as default values creates a problem in COSYMA which is a **European** code system; many of these data are derived from national statistics and thus will vary from country to country. The set of economic default data that is included in COSYMA refers to the economic situation of the "old" Federal Republic of Germany (i.e. without the former German Democratic Republic). Another set of economic

default values that refers to the United Kingdom is presented additionally in the User Guide /3/.

The user who wants to perform calculations applicable to another European country may either establish his own set of default values for use in **ECONOM at the time of implementing** the whole program package or he may change the default values in each run with the FORTRAN namelist input procedure that is offered in COSYMA. It should also be mentioned that the monetary unit (M.U.) used in **ECONOM** is not pre-determined, it will be determined by the currency of the input costs and thus is subject to user input. (It is evident, of course, that all input costs have to be expressed in the same currency unit).

Another problem with economic input data is characterised by the question: "At what time did the accident occur?" In other words: economic input data are not only area-dependent but also time-dependent, i.e. they may vary from year to year. All economic default data for the Federal Republic of Germany are adjusted to the **base year 1989**; this means that the economic consequences calculated with **ECONOM** reflect the economic situation of Germany in 1989.

This is true not only for the time of occurrence of the accident but also for the following years. In other words: if the impact of an accident extends over a couple of years, a "static" national economy is assumed in the model, i.e. there will be no changes, either in the population (number of people, age distribution, etc.) or in the circulation of goods and services (amount and prices) within the national economy.

## **2.4 Economic Consequences of Sheltering**

Sheltering is a measure that normally precedes the forced movement of people, i.e. evacuation or relocation (which will be treated in more detail in the following Section 2.5). If this is the case, sheltering costs are included in the costs of forced movement, and, as they are low in comparison with the costs of the total movement taken together, it is not necessary to evaluate them separately.

There might, however, be a situation in which sheltering is considered to be the only countermeasure to be applied. For this case, the subsystem **NL** of COSYMA allows sheltering costs to be evaluated explicitly. The sheltering area is defined by the user by the radius of the sheltering area, the duration of sheltering is on the order of a few days and has also to be defined by the user. The costs are calculated in terms of the Gross Domestic Product (GDP) lost during that period (see calculation of loss-of-income costs in case of relocation, Section 2.5.1).

## **2.5 Economic Consequences of Forced Movement of People**

### **- Evacuation / Relocation**

In order to protect people from a high radiation exposure in case of an accidental release, they may be forced to leave their homes for a certain period of time. If this movement aims at reducing the short-term or acute radiation exposure during and shortly after the release, it is normally called **Evacuation**; the duration of absence in this case may be on the order of days up to a few weeks. If the aim is to reduce the continuing or long-term exposure due to deposited radionuclides, the movement is called **Relocation**; in this case, the absence may last months or years, if not forever. (For more details on the general modelling of countermeasures, see /5/).

**Evacuation** is treated in the subsystem NE of COSYMA, the initiating criteria being either a geometrically defined evacuation zone or a user-specified dose. In this connection, only the process of moving people out of the area is considered in detail; no information is available about the end of the evacuation process - i.e., whether people may be resettled to their homes at some later date or whether evacuation develops into a longer lasting relocation. The user has to specify a value for the duration of evacuation and has to be aware of the fact that the costs calculated refer only to that period of time.

**Relocation** is treated in the subsystems NL and FL of COSYMA; in both cases, the user has to specify dose values as a criterion applied to initiate and to terminate relocation. The program enables the user to specify a time-frame with up to 15 periods of time for the end of a relocation process (the default value of the end of the last period is 70 years). Resettlement is possible in each part of the area considered (i.e. in each grid element of the  $r, \phi$ -grid) at the end of each period of time, provided that the dose criterion of return is fulfilled.

In the subsystem NL the resettlement criteria may also be applied to people that have been assumed to be evacuated. For this, the information about evacuation areas calculated in the subsystem NE is transmitted to the subsystem NL. In particular, evacuated people might stay away for a longer period of time, even if the relocation criterion did not justify a movement. This means that a clear distinction cannot be made between evacuated and relocated people in the subsystem NL.

Finally, in the subsystem FL only the relocation costs are considered, because evacuation is not assumed to be a measure which would be applied beyond a distance of more than several tens of kilometres.

In the following sections, the calculational procedure used for evacuation and relocation will be treated in more detail. Relocation costs will be treated first because the underlying procedure is more general than the procedure for evacuation.

## 2.5.1 Relocation

### 2.5.1.1 Cost Categories

The following cost categories contribute to relocation costs:

- transport costs,
- accommodation costs,
- loss-of-income costs,
- costs of lost capital services.

**Transport** costs include the direct expenditures due to the movement of people away from and back to the relocation area, either by private cars or public transport means.

**Accommodation** costs include the costs incurred when people cannot use their own dwellings or houses in the relocation area and additional accommodation has to be provided outside. The time of absence in case of relocation is rather long on the average, and accommodation costs are assumed, therefore, as a lost benefit of the dwellings and houses in the relocation area during that time.

**Note:** Capital investments that are needed for the construction of new accommodation outside the affected area are not allowed to be considered at the same time as accident costs, because this would imply that the same economic performance is counted twice.

**Loss-of-income** costs are a lost benefit to the economy due to the fact that production facilities cannot be operated in the relocation area during the time of the ban. The lost economic output (i.e. the "value added") to the national economy of the non-produced goods and services in the relocation area is regarded as loss-of-income costs.

**Note:** The model philosophy implies that the loss of production of goods and services can be compensated from outside the relocation area under the same conditions (in amounts and prices). In other words: The economic impact of an accident is assumed to be limited to the directly affected areas and would not lead to any changes in the production and distribution (consumption) of goods and services (in amount and prices) within the whole national economy. It should be noted that this is a rather stringent restriction that may only be plausible if the relocation area is small in comparison with the total area of the national economy and/or if this area did not contain any vital production facilities (e.g. an international airport).

The costs of **lost capital services** are also a lost benefit to the national economy, because it is not possible to use capital investments within the relocation area during the duration of relocation. It is assumed that the capital is further depreciated also in the case of non-use which results in losses to the economy. The costs of lost capital services are

split into  $K = 4$  components: (1) non-residential capital, (2) houses and buildings, (3) consumer durables, and (4) land.

For long-term relocation, it is assumed that after a certain time people become integrated again into the normal course of economic production outside the relocation area, and thus no further costs of accommodation and loss-of-income will occur. This "cut-off time" or "recovery time" is a user-specified value, and costs of accommodation and loss-of-income are calculated only up to that time. As the Gross Domestic Product - GDP - (see below) is used as a basis for calculating loss-of-income costs, and as the depreciation of (1) non-residential capital and (2) houses and buildings is included in GDP, the calculation of these two components of lost capital services starts from  $T = \text{recovery time}$  in order to avoid double counting. On the other hand, calculation of the components (3) and (4) of lost capital services will start from  $T = 0$ .

Several options may be used for each of the cost categories:

For the calculation of **transport** costs two options are available, one with breakdown of costs within the time-frame and discounting of the return journey, and another with no time-breakdown and costs based on the outward journey multiplied by two to cover the costs of the return journey.

For **accommodation** costs, **loss-of-income** costs and costs of **lost capital services**, option 1 is the method that may be used if single, average, site-dependent unit costs are available; the calculation is based in this case on the number of people and the area relocated, respectively. Option 2 may be used if region-specific unit costs are available. Pre-calculation of the number of people moved and of the areas in each economic region and in each period of time is necessary; it has to be based on the flags of the relocation area obtained from preceding COSYMA modules. An additional data set is required in which, for each nuclear site, each grid element of the  $r, \phi$ -grid is assigned to an economic region.

For **loss-of-income** costs, an additional option 3 is offered in which the so-called land-use grid method is applied. The calculation is also based on the flags of the relocation area, and the cost calculations are performed on a grid element by grid element basis. For this purpose, an additional data set is necessary in which, for each nuclear site, for each grid element the annual GDP is given for the area of the grid element (= land-use grid).

**Note:** The additional data sets necessary in the calculations with options 2 and 3 are not included in the COSYMA program package and have to be provided - if needed - by the user himself.

### 2.5.1.2 *Input Data*

The information that is available from **preceding COSYMA modules** is either the number of people and the corresponding area as a function of the duration of relocation, or, on a grid element by grid element basis, a flag for each grid element in the  $r,\phi$ -grid that assigns this element to the relocation area; the value of the flag is the index of the period of time in which relocation ends.

The input values provided by the **user** have to be derived in most cases from statistics of the national economy of the country in which the nuclear sites are located.

For the determination of unit transport costs (in monetary units/cap) the specific costs of running a car for both private and public transport, the average car occupation and the average distance between the relocation area and the area to which people move (destination area) have to be taken into consideration.

The unit cost values for loss-of-income costs (in monetary units/cap-year) are derived from the national or regional **Gross Domestic Product (GDP)**, at factor costs). GDP is a standard quantity in National Account Statistics; it is a measure of the economic productivity in terms of the "value added" of goods and services produced in an area in a certain period of time (normally one year). If food ban costs are calculated, the fraction of agricultural production has to be subtracted - if possible - from total GDP in order to avoid double counting. If accommodation costs are calculated, the housing component has to be subtracted - if possible - for the same reason.

Regarding accommodation costs, the unit costs are different for the two options: for option 1 it is recommended to use the housing component of GDP (in monetary units/cap-year); for option 2 the average market value of houses and dwellings (in monetary units/cap) is used in the cost calculations. In this case, a depreciation rate has to be specified additionally to obtain annual costs.

Unit cost values for lost capital services (in monetary units per cap and per area, resp.) may also be derived from national statistics or have to be estimated from other sources.

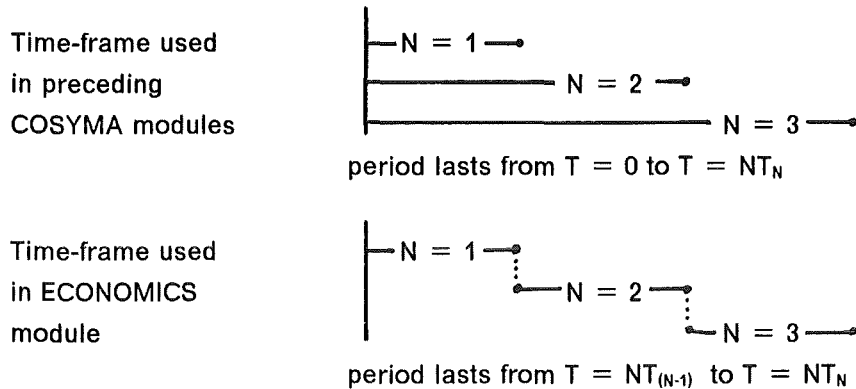
### 2.5.1.3 *Principle of Cost Calculations*

As already mentioned at the beginning of Section 2.5, a time-frame is used to calculate the impacts of relocation

$$NT_N, \text{ with } N = 1 \text{ to } N = NNT,$$

where  $NT_N$  indicates user-specified periods of time that last from  $T = 0$  to  $T = NT$  for each period  $N$ . At the beginning of establishing the ECONOMOCS module, it seemed

reasonable not to use the periods of time defined originally from the preceding COSYMA modules to calculate time-dependent costs, because the periods are overlapping in this case, but to use instead a slightly modified definition where the periods of time follow each other in sequence, as can be seen below:



At a later stage of establishing the ECONOMICS module it was found helpful to use in addition the originally defined periods of time for calculating time-dependent costs. This gives several categories of time-dependent costs that are used in the ECONOMICS module and are called "TYPE A", "TYPE B" and "TYPE C" costs:

- "TYPE A" costs refer to all impacts that occur in the **redefined** periods,
- "TYPE B" costs are defined as the sum of all "TYPE A" costs from period = 1 to period = N,
- "TYPE C" costs refer to the impacts that occur in the **originally defined** periods of time. \*)

The fundamental procedure applied to calculate the four categories of relocation costs in each period of time N is as follows:

**Transport** costs (outward or return, private or public) - both options:

$$C\text{-TRA}_N = \text{number of people moved within each period } N \text{ (cap)}$$

- unit transport costs (M.U./cap)

\*) Practical example: assume  $N = 6$ ,  $NT_6 = 5$  years and  $NT_5 = 2$  years; the number of people relocated have to be expressed in terms of costs. The different categories of time-dependent costs are as follows:

"TYPE A" costs of  $N = 6$  refer to **all** people that are relocated in the **redefined** period of time, i.e. between 2 and 5 years (relocation may end for these people at  $T = 5$  years **or later**).

"TYPE B" costs of  $N = 6$  sum up all "TYPE A" costs from  $N = 1$  to  $N = 6$ , i.e. "TYPE B" costs constitute the **total** costs incurred between  $T = 0$  and  $T = 5$  years.

"TYPE C" costs of  $N = 6$  refer to those people relocated within the originally defined period of time from  $T = 0$  to  $T = 5$  years, i.e. to all people for whom relocation **ends** at  $T = 5$  years.

### Accommodation costs:

#### Option 1

$$\begin{aligned} \text{C-ACC}_N &= \text{number of people relocated within each period } N \text{ (cap)} \\ &\bullet \text{ housing component of GDP (M.U./cap-year)} \\ &\bullet \text{ duration of period } N \text{ (years)} \end{aligned}$$

#### Option 2

$$\begin{aligned} \text{C-ACC}_N &= \text{number of people relocated within each period } N \text{ (cap)} \\ &\bullet \sum_{NN} \text{ capital value of houses or dwellings in the year } NN \text{ (M.U./cap)} \\ &\bullet (\text{depreciation} + \text{interest rate}) \text{ (1/year)} \end{aligned}$$

where

$$NN = \text{years within period } N.$$

### Loss-of-income costs

#### Options 1 and 2:

$$\begin{aligned} \text{C-LOI}_N &= \text{number of people relocated within each period } N \text{ (cap)} \\ &\bullet \text{ GDP (M.U./cap-year)} \\ &\bullet \text{ duration of period } N \text{ (years)} \end{aligned}$$

#### Option 3:

$$\begin{aligned} \text{C-LOI}_N &= \text{GDP summed up over all grid elements of the relocation area} \\ &\text{that refer to period } N \text{ (M.U./year)} \\ &\bullet \text{ duration of period } N \text{ (years)} \end{aligned}$$

### Costs of lost capital services - options 1 and 2

(for capital components K see p. 10):

$$\begin{aligned} \text{C-LCS}_N &= \text{number of people relocated within each period } N \text{ (cap)} \\ &\bullet \sum_{NN} \sum_{K=1}^3 \text{ capital value of component } K \text{ in the year } NN \text{ (M.U./cap)} \\ &\bullet (\text{depreciation rate } K + \text{interest rate}) \text{ (1/year)} \\ &+ \\ &\text{relocation area in each period } N \text{ (m}^2\text{)} \\ &\bullet \sum_{NN} \text{ capital value of land (} K = 4 \text{) in the year } NN \text{ (M.U./m}^2\text{)} \\ &\bullet (\text{depreciation rate land} + \text{interest rate}) \text{ (1/year)} \end{aligned}$$

Whenever costs are incurred beyond the first year, they are obviously discounted.

## 2.5.2 Evacuation

The cost categories that contribute to evacuation costs are the same as in the case of relocation, but the model philosophy is slightly different because of the much shorter time of absence that is assumed in the case of evacuation.



The unit costs of **transport** are lower because a smaller distance is assumed to exist between the evacuation area and the destination area.

**Accommodation** costs of option 1 are not calculated on the basis of the contribution of housing to GDP (although this fraction is subtracted from total GDP in order to avoid double counting in calculating loss-of-income costs), but are calculated on the basis of direct expenditures in the destination area - this leads to higher unit cost values. In other words: no loss of value of houses or dwellings is assumed for the evacuation area during the (short) duration of evacuation, but instead the direct expenditures for accommodation outside the evacuation area are taken into account. Option 2 of accommodation costs is treated in the same way as in case of relocation.

For the calculation of **loss-of-income** costs, agricultural production is not subtracted from total GDP, because food bans are not considered in connection with evacuation.

The cost category of **lost capital services** is not treated separately, because two of the four capital components ( (1) non-residential capital, (2) houses + buildings) are included in loss-of-income costs by the use of GDP, and the latter two - (3) consumer durables and (4) land - are not assumed to decrease substantially in value during a period of days, or weeks at the most.

The calculation methods are similar to those described in Section 2.5.1.3 on relocation, although much simpler, as only one period of time has to be considered and discounting is not necessary because all costs are assumed to be incurred in the evacuation period or immediately afterwards, i.e. within the first year.

## **2.6 Economic Consequences of Decontamination**

Decontamination is a countermeasure that is applied in COSYMA in connection with relocation in order to accelerate resettlement. The same periods of time are used as in the case of relocation. The level of decontamination is determined by a time-dependent value; this enables the user (a) to define the periods of time in which decontamination is applied, and (b) to use different decontamination levels or levels of effectiveness in each period.

### **2.6.1 Cost Categories**

Only one cost category is calculated for decontamination - i.e. overall decontamination costs - but there are two options available for the cost calculations. Option 1 is based on the **area** only; no distinction is made between decontamination in rural and urban areas, and only **one** set of average unit costs is assigned. Option 2 is a first-order approximation

if the user wants to distinguish between decontamination in rural areas and decontamination in urban areas. In this case, the (total) **area** is multiplied by a factor that gives the average, site-dependent fraction of rural/total area of the site, and is thus attributed to **rural**. On the other hand, the number of **people** is used as a basis to indicate the effort of decontamination in **urban** areas.

## 2.6.2 Input Data

The information available from preceding COSYMA modules is the area to be decontaminated in each period of time, and the number of people living in that area.

The unit costs used in the calculations strongly depend on the decontamination techniques assumed to be applied. Information from practical experience is rather poor, and the user has to rely mostly on theoretical investigations. The default values used in the ECONOMICS module have been collected by NRPB (for more details see /2, 6/).

## 2.6.3 Principle of Cost Calculations

Decontamination is assumed to take place at the end of each period of time, i.e. costs are incurred at distinct points in time and not during the period. This means that time-dependent costs of "TYPE A" and "TYPE C" are identical (for details see Section 2.5.1.3, p. 12), and, therefore, "TYPE C" costs are not calculated in this case.

The fundamental procedure applied for the cost calculations in each period of time N is:

Option 1:

$$\begin{aligned} \text{C-DEC}_N &= \text{area to be decontaminated in each period N (m}^2\text{)} \\ &\quad \bullet \text{ unit costs of decontamination per area (M.U./m}^2\text{)} \end{aligned}$$

Option 2:

$$\begin{aligned} \text{C-DEC}_N &= \text{area to be decontaminated in each period N (m}^2\text{)} \\ &\quad \bullet \text{ fraction of rural/total area ( - )} \\ &\quad \bullet \text{ unit costs of decontamination per area (M.U./m}^2\text{)} \\ &+ \\ &\quad \text{number of people living in the area in each period N (cap)} \\ &\quad \bullet \text{ unit costs of decontamination per capita (M.U./cap)} \end{aligned}$$

Whenever costs are incurred beyond the first year, they are obviously discounted.

## 2.7 Economic Consequences of Food Bans

Food bans, i.e. the ban on the production and distribution (consumption) of foodstuffs that have been produced in a certain area, is a countermeasure that is applied in COSYMA in order to reduce the radiological exposure by ingestion. Food bans can be assumed to be imposed or withdrawn on the basis of intervention levels, either based on activity levels in food or on individual doses.

A time-frame is used for the calculation of food bans, but, in contrast to relocation, numerical values of the periods cannot be selected by the user; they are determined by the food chain transport models within the ingestion module of COSYMA which supply the activity levels in food data /7/. Withdrawal of a food ban is possible in each part of the area considered, i.e. in each grid element of the  $r,\phi$ -grid, provided that the criterion for withdrawal of the ban is fulfilled.

### 2.7.1 Cost Categories

Three cost categories contribute to food ban costs:

- costs of lost food,
- costs of lost agricultural capital,
- costs of disposal of food.

The costs of **lost food** include the lost benefit either of (A) agricultural products for which production has not been stopped for a certain period of time after the accident and which are not allowed to be consumed due to high contamination levels, or of (B) products that are not allowed to be produced after the accident during the period of the ban. The spectrum of agricultural products may not be assumed to be stationary over the year in all cases; this means that both cases (A) and (B) may be possible for different agricultural products within a certain period of time after the accident. After that time, it is evident that only case (B) has to be taken into consideration.

Therefore, in order to be conservative, it is assumed for the modelling of the costs of lost food that **all** agricultural products are treated according to (A) in the first year and according to (B) in the following years. In other words: in the first year after the accident, normal production throughout the year is assumed, but the products will not be used for consumption; in the following years the philosophy is the same as for loss of income costs in case of relocation, i.e. the farmer (and his employees) may suffer from loss of income because of non-production of agricultural goods.

The costs of **lost agricultural capital** are calculated according to the same philosophy as described in Section 2.5.1 on relocation; within the category of food ban costs, the agricultural capital investments are broken down into  $K = 3$  components, namely (1) non-residential capital, (2) buildings, and (3) agricultural land.

**Food disposal** costs include all direct expenditures for the disposal of produced but contaminated products. It is assumed that this type of costs are incurred only in the first year.

In the same way as in case of relocation, a "recovery time" may be assumed by the user after which the farmers may have found agricultural areas and thus new production capabilities outside the food ban area; and calculation of the costs of lost food is cut off at that time. As the depreciation of non-residential capital and of buildings is included in the costs of lost food (by using gross output or GDP data - see below), the calculation of these two components of the costs of lost agricultural capital starts only from  $T =$  recovery time in order to avoid double counting; calculation of the third component - agricultural land - will start from  $T = 0$ .

In the present version of ECONOM, only one option is available for the cost calculations. This option is based on the agricultural production grids that are available within the overall COSYMA program package.

### 2.7.2 Input Data

European agricultural grids will be used in COSYMA, and the information available from **preceding COSYMA modules** for the calculation of economic consequences of food bans are the yearly amounts of specific "agri-economic" products in each period of time ("agri-economic" products stands for **agricultural** products that are combined in a proper way for the calculation of **economic** consequences).

Up to five agri-economic products may be treated in ECONOM, and, according to the agricultural production grids presently available, three types of products are actually treated, namely **milk**, **livestock** and **crop area**; the foodstuffs considered in preceding COSYMA modules have to be combined in such a way that they are represented by the three agri-economic products mentioned.

The input values provided by the **user** have to be derived from statistics of the agricultural sector of the national economy of the country in which the nuclear sites are located.

The unit cost values of lost food for each agri-economic product are based in the first year on the **gross output** of and in the following years on the **GDP contribution** to each product.

The unit cost values of lost agricultural capital describe the capital investments necessary for the production of each agri-economic product; it is assumed that these investments cannot be used during the period of the food ban.

The unit cost values of food disposal refer to all activities aiming at the safe and ultimate disposal of contaminated products. It is evident that these costs strongly depend on the techniques applied. There is hardly any practical experience available on the disposal of food; therefore, numerical values can only be based on very rough estimates.

The German default values of the unit costs referring to the agri-economic products are based on the **kilogramme** as the unit quantity of production. But in principle, other unit quantities of production may be selected by the user to determine unit cost values. This is possible because conversion factors are included in the cost calculations for the transfer of the unit quantities of the agri-economic production grids into the unit quantity of products used in the unit costs (for details, see Section 4.3.3).

### 2.7.3 Principle of Cost Calculations

As already mentioned, a time-frame is used for the calculation of food bans; this time-frame has been modified in the same way and leads to the same categories of time-dependent costs "TYPE A", "TYPE B" and "TYPE C" as in case of relocation (for details, see Section 2.5.1.3 on p. 12).

The fundamental procedure applied to calculate the three categories of food ban costs in each period of time N for each agri-economic product IEC is as follows:

Costs of **lost food**:

$$C\text{-LOF}_{\text{IEC},N} = \text{amount of product IEC in each period N (####/year)}$$

- unit costs of lost food (M.U./kg)
- conversion factor (kg/####)
- duration of period N (years)

where

#### = unit quantity of the different production grids.

### Costs of lost agricultural capital

(for capital components K, see p. 17):

$$\begin{aligned} C\text{-LAC}_{\text{IEC},N} = & \text{amount of product IEC in each period N (###/year)} \\ & \bullet \sum_{NN} \sum_{K=1}^2 \text{capital value of component IEC,K in year NN (M.U./(kg/year))} \\ & \quad \bullet \text{conversion factor (kg/###)} \\ & \quad \bullet \text{(depreciation rate K + interest rate) (1/year)} \\ & + \\ & \text{amount of product IEC in each period N (###/year)} \\ & \bullet \sum_{NN} \text{capital value of land in the year NN (M.U./km}^2\text{)} \\ & \quad \bullet \text{conversion factor (km}^2\text{/###/year)} \\ & \quad \bullet \text{(depreciation rate land + interest rate) (1/year)} \end{aligned}$$

where

NN = years within period N.

### Food disposal costs:

For all periods of time within the first year:

$$\begin{aligned} C\text{-DIS}_{\text{IEC},N} = & \text{amount of product IEC in each period N (###/year)} \\ & \bullet \text{unit disposal costs (M.U./kg)} \\ & \bullet \text{conversion factor (kg/###)} \\ & \bullet \text{duration of period N (years)} \end{aligned}$$

Whenever costs are incurred beyond the first year, they are obviously discounted.

## 2.8 Economic Consequences of Health Effects

The primary impact of a nuclear accident are the radiation-induced detriments to health in the affected population living in the vicinity of the site as well as at far distant areas. There are three main categories of health effects that are incurred:

- deterministic non-fatal and fatal effects,
- stochastic somatic non-fatal and fatal effects (= cancers),
- stochastic hereditary effects.

Note: The first category is called in COSYMA "early health effects", the latter two categories taken together are called "late health effects".

Impacts of the first category are treated in the subsystem NE, impacts of the latter two categories in the subsystems NL and FL of COSYMA. This distinction is also made to calculate economic consequences with one exception: the subsystem NL of ECONOM is established as a version by which the costs of **all** countermeasures and **all** health effects

of the near range may be treated; thus, the user will also have the possibility to calculate the costs of early health effects in the subsystem NL.

In detail, the following effects are considered in COSYMA:

**Deterministic health effects**

Note: The effects are different for non-fatal and fatal effects, the sequence is identical in ECONOM and the preceding modules:

	Non-fatal effects	Fatal effects
(1)	lung function impairment	pulmonary syndrome
(2)	hypothyroidism	hematopoietic syndrome
(3)	cataracts	gastrointestinal syndrome
(4)	mental retardation	pre-/neonatal death
(5)	effects on skin	skin burns

**Stochastic somatic effects = cancers**

Note: The following list includes the various **organs** in which cancers may occur. The sequence of organs is the same for non-fatal and fatal effects, but is different in ECONOM and the preceding modules:

	In preceding COSYMA modules:		In ECONOM:
(1)	bone marrow	(1)	bone marrow
(2)	bone surface	(2)	bone surface
(3)	breast	(3)	breast
(4)	lung	(4)	lung
(5)	stomach		
(6)	colon	(5)	GI-tract = stomach + colon + liver + pancreas
(7)	liver		
(8)	pancreas		
(9)	thyroid	(6)	thyroid
(10)	remainder tissues	(7)	remainder tissues
(11)	skin	(8)	skin

**Stochastic hereditary effects**

Hereditary effects are treated separately in ECONOM. There is no breakdown into different categories.

## 2.8.1 Cost Categories

The monetary quantification of health effects is of rather controversial nature because it implies quantifying the value of human life. Two approaches are incorporated in ECONOM: (1) the "Subjective Valuation" approach and (2) the "Human Capital" approach. The cost categories are different for the two approaches.

In the **Human Capital** approach, two cost categories are assumed to contribute to health effect costs, namely

- costs of medical treatment,
- losses of an individual's contributions to the economy.

The first category - as reflected by its name - includes all direct expenditures for the treatment of a health detriment. The latter is based on the assumption that each individual in the society has an economic production potential that is put at the society's disposal during his or her life time. The economic impact of a health detriment results in a partial or total interruption of this production potential; and the losses are calculated by multiplying the number of years of life lost for each type of health effect by a unit cost value per year lost.

In the **Subjective Valuation** approach, a monetary value is assigned to each health effect according to individual preferences which constitutes the amount of money an individual would be willing to pay in order to avoid an increased risk originated from that effect. Only one cost category is considered in this case which should include both categories mentioned above.

This results in the following options for calculating the costs of health effects:

	Early effects	Late effects
Option 1:	Subjective valuation approach: all types of health effect	Subjective valuation approach: cancers
Option 2:	Human capital approach: all types of health effect	Human capital approach: cancers
Option 3:	- - -	Subjective valuation approach: cancers + hereditary effects
Option 4:	- - -	Human capital approach: cancers + hereditary effects



## 2.8.2 Input Data

The following information is available from **preceding COSYMA modules**:

for early health effects: the number of effects of each type of health effect, of non-fatal and fatal effects;

for late health effects: the number of fatal cancers of each cancer type of the living generations, and the following generations, the number of hereditary effects of the 1st generation following the living generations, and the following generations.

The numbers of non-fatal cancers are calculated for each cancer type with the help of a user-specified correction factor for cancer incidence ( = ratio of fatal to total cancers).

The input values that have to be provided by the **user** are different for the two approaches of cost calculations. For option 1 (and option 3), only one set of unit costs is needed, and - as is evident from the name of this approach - this set is determined by individual preferences of the user. He may find some hints in the literature for the derivation of such values (see e.g. /2/).

For option 2 (and option 4), unit costs have to be provided for medical treatment and for losses to the economy. The first set of values may be derived - if available - from national disease statistics for different health detriments. Such statistics are not available for the Federal Republic of Germany and the relevant data have been taken from the NRPB publication /2/. Unit costs of losses to the economy should be based on statistical data of the average yearly earnings of individuals in a national economy.

In addition, the user has to specify the "effective" duration of medical treatment for early and late health effects ("effective" in this case means the period of time for which cost calculations are performed), and the number of years of life lost due to premature death for early health effects (the number of years of life lost due to premature death for late health effects are included in the code).

## 2.8.3 Principle of Cost Calculations

The fundamental procedure applied for the cost calculations of each type of health effect is as follows:

**Costs of early health effects:**

Option 1

$C\text{-TOT}_{\text{NOG}}$  = number of health effects for each type NOG (cases)

- unit costs for each type NOG (M.U./case)

Option 2

Costs of medical treatment:

$C\text{-MED}_{\text{NOG}}$  = number of health effects for each type NOG (cases)

- unit costs of medical treatment for each type NOG (M.U./case)

Costs of losses to the economy:

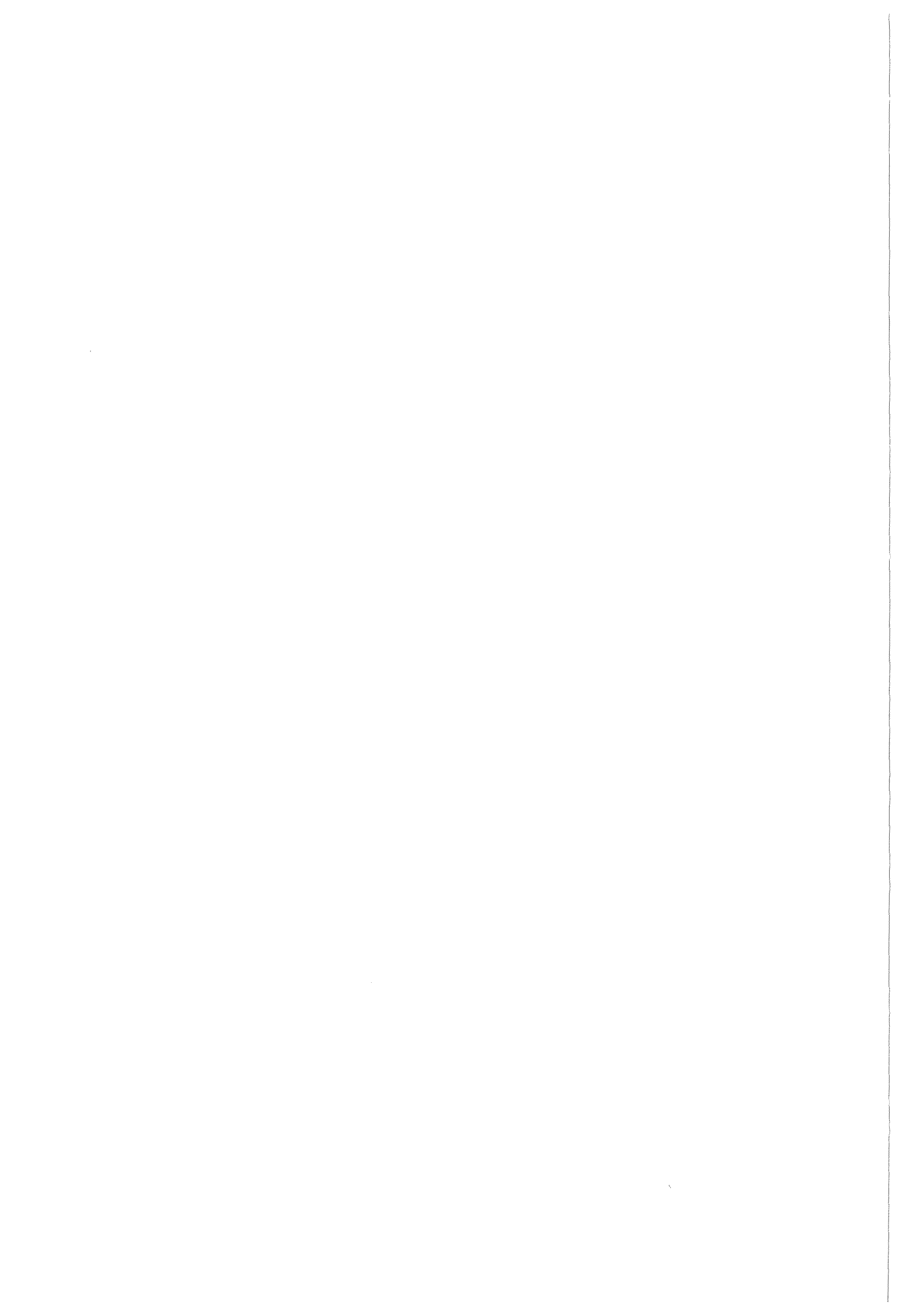
$C\text{-LOE}_{\text{NOG}}$  = number of health effects for each type NOG (cases)

- unit costs of losses to the economy (M.U./case-year)
- "effective" duration of losses to the economy for each type NOG (years).

**Costs of late health effects:**

The principal calculational procedure is the same as for early effects, the difference is that - in case of cancers - a time-frame is used and costs are, therefore, calculated as dependent on time.

Whenever costs are incurred beyond the first year, they are obviously discounted.



### 3. Description of the ECONOMICS Module

In this chapter, a detailed description of the calculational procedure applied in the ECONOMICS module is presented. The structure of the module is shown in Fig. 1, and this structure is also used as a guideline for the description. As can be seen from Fig. 1, the ECONOMICS module is split into two major parts. The first part, ECONOM, is subdivided into quite a number of submodules in which the cost calculations are performed for the various impacts of an accident. In the second part, EVAECO, the results calculated in ECONOM may be further processed for numerical or graphical presentation. Only the ECONOM module will be described in greater detail below, in the EVAECO module standard procedures are used that are applied throughout the whole COSYMA program package.

**Note:** All user input data mentioned in this chapter are indicated in *ITALICS*.

The parameter names used in this chapter - with very few exceptions only - are identical with those used in the FORTRAN source program.

The ECONOM module can be called by the main program of COSYMA in each subsystem NE, NL, FL by using a steering parameter called *NOECON*. The user must ensure that all information required from preceding modules is available when ECONOM is called. As can be seen from Fig. 1, ECONOM is designed in a modular form: each impact of an accident may be converted into costs independently of the others in a separate submodule by using a special steering parameter. These submodules and the respective steering parameters refer to the following main cost categories:

SHECOS == > sheltering costs,  
EVACOS == > evacuation costs,  
RELCOS == > relocation costs,  
DECCOS == > decontamination costs,  
FOBCOS == > food ban costs,  
EHECOS == > early health effect costs,  
LHECOS == > late health effect costs.

At the beginning, the ECODAT submodule is called to check the steering parameters and to provide a printout of all ECONOM-specific input data used in that run. An additional submodule, TOTCOS, calculates at the end of ECONOM the total costs of all categories treated in this run.

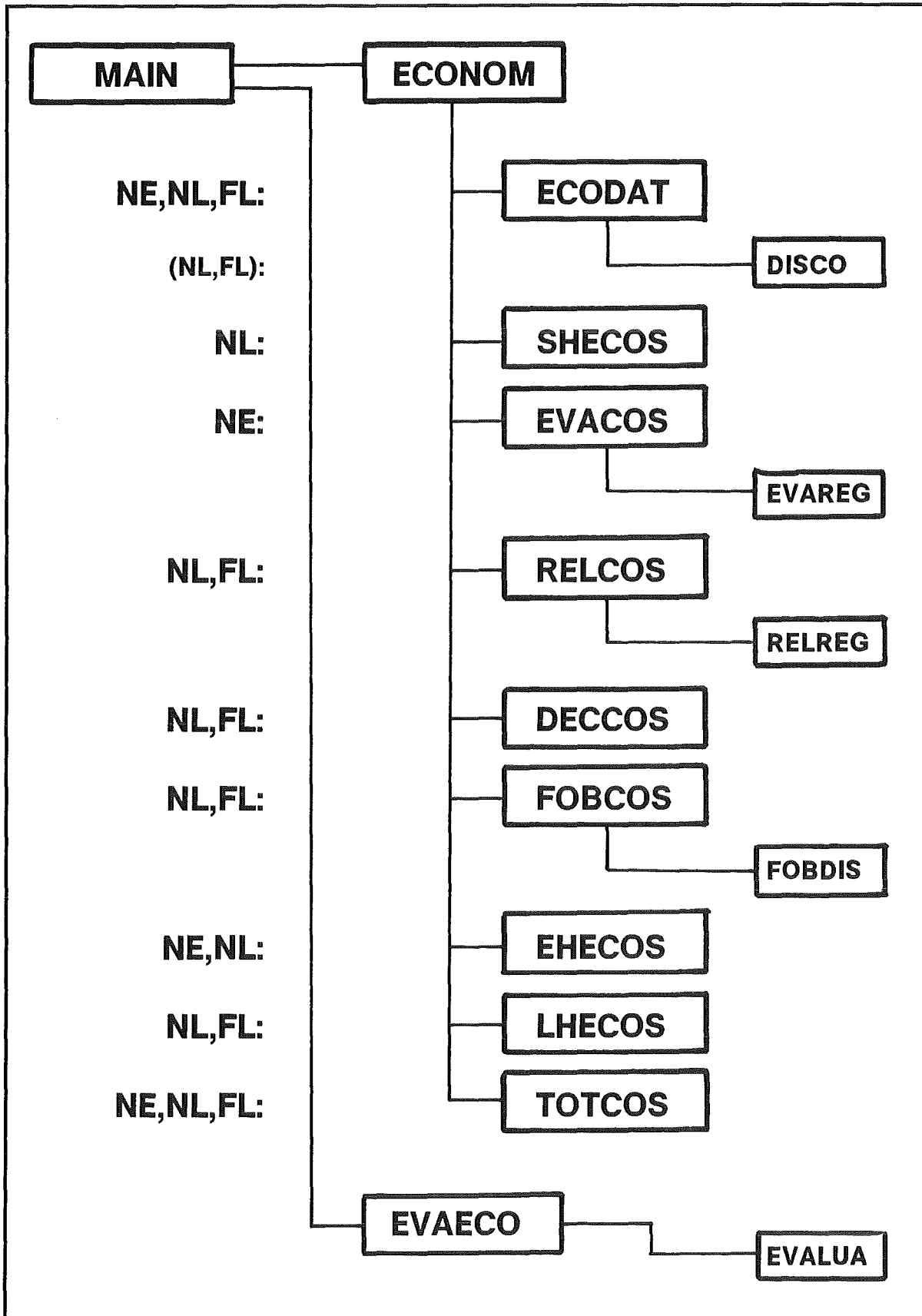


Figure 1: Structure of the ECONOMICS Module

### 3.1 ECODAT Submodule

The ECODAT submodule is called automatically in each COSYMA subsystem NE, NL, FL. In the subsystems NL and FL of ECODAT, first some user input data that have already been used in preceding COSYMA modules and are relevant also in ECONOM, are read in and checked - if necessary - for their consistency with the parameters used in ECONOM. There is an error message and run is terminated if consistency is not fulfilled.

Next, ECODAT checks in all subsystems NE, NL, FL whether the steering parameters are correct that are used to call the following submodules in ECONOM in order make the cost calculations. The value of such a steering parameter does not only indicate whether or not a specific main cost category is treated but also defines the option(s) used for the calculations.

**Note:** For these steering parameters only those values are admissible that are indicated in Section 4.2.1. If the user selects a value of a steering parameter that is different from those indicated - and, therefore, not permitted - ECODAT gives an error message and the run is terminated.

If the check has been carried out successfully for a steering parameter of a main cost category a printout is provided with all user input data used in that run which refer to that cost category.

It should be mentioned here that the user has the possibility to adjust in ECONOM all input data of unit costs with the help of special multiplication factors

<i>FUCEC</i>	for sheltering, evacuation and relocation costs,
<i>FUCDC</i>	for decontamination costs,
<i>FUCFB</i>	for food ban costs,
<i>FUCEH</i>	for early and late health effect costs.

For more details, see description of these parameters in Chapter 4..

Note: The multiplication is carried out in ECODAT and the printout presents already the multiplied values.

#### 3.1.1 DISCO Subroutine

The DISCO subroutine is called by ECODAT if either the steering parameter for the calculation of relocation costs, *ICREL*, or that for decontamination costs, *ICDEC*, is  $> 0$ . In both cases, a time-frame

$NT_N$  with  $N = 1$  to  $N = NNT$

is applied, and in DISCO all precalculations are carried out in order to determine the discount factors, the time-integrated values and other auxiliary parameters that are used for the calculation of relocation and decontamination costs.

In order to better understand the following calculational procedures, some general explanations will be given on p. 29 on the discounting of costs and the depreciation of capital values.

The following calculations are carried out in DISCO:

The original time scale  $NT_N$  (the values given in days) is converted into years (yr); the number of periods of time are determined that cover the first year (this is necessary because there is no discounting in these periods); all values  $> 1$  year are rounded off to integer values  $NTZ_N$ .

Next, the recovery time  $TREC$  (see Section 2.5.1.1) is introduced, and the values

$NTR$  = index of last period for the calculation of transport costs,

$NAC$  = index of last period for the calculation of accommodation and loss-of-income costs

are calculated.

Finally, the discount factors and the time-integrated values are calculated. These calculations are rather complicated because  $TREC$  may have any real value  $> 0$  and  $< NTZ_{NNT}$ , and, therefore, the period of time into which  $TREC$  falls, must be split into two parts. It is not necessary to give details of the method of calculation here; to enable the reader to understand the calculations it is sufficient to illustrate the basic procedure which is as follows:

### Relocation

Discount factors - Transport costs

For all periods of time within the first year:

$$DFTR_N = 1.0$$

For all other periods:

$$DFTR_N = QRL^{-NTZ_N + 1}$$

with

$$QRL = 1 + (DISRL/100)$$

where

$DFTR_N$  = discount factor in each period  $N$  (-),

$DISRL$  = discount rate (%/yr),

$NTZ_N$  = last year of period  $N$  for all periods beyond the 1st year.

## Digression: Discounting and Depreciation

A cost value  $C$  incurred in the year  $t = T$  is discounted to the first year as follows:

$$C_{\text{DIS}} = C \cdot Q^{-T+1}$$

with

$$Q = (1 + \text{DIS} / 100)$$

where

$$\text{DIS} = \text{discount rate (\%/yr)}.$$

Equal cost values  $C$  incurred each year within a period from  $t = 1$  to  $t = \text{DUR}$  can be added and discounted at the same time by the following calculational method:

$$C_{\text{TOT}} = C \cdot Q^0 + C \cdot Q^{-1} + C \cdot Q^{-2} + \dots + C \cdot Q^{-\text{DUR}+1}$$

The equation above can be written as

$$C_{\text{TOT}} = C \cdot \text{TIVA}$$

with

$$\text{TIVA} = Q^0 + Q^{-1} + Q^{-2} + \dots + Q^{-\text{DUR}+1}$$

$$= \sum_{t=1}^{\text{DUR}} Q^{-t+1} = (1 - Q^{-\text{DUR}}) / (1 - Q^{-1})$$

The expression TIVA includes the duration of the period and the discounting applied in each year; the unit of TIVA is years.

If a capital value CAPIT is to be depreciated with a depreciation rate DEPR applied, this means that in each year a fraction of DEPR (in absolute values) is subtracted from CAPIT. There are, in principle, two modes of calculating the depreciation: 1) the linear mode: in this case the fraction DEPR in each year refers to the **initial** value of CAPIT and after a certain number of years the initial value has been depreciated to zero; 2) the exponential mode: in this case the fraction DEPR in each year refers to the **actual** value of CAPIT in that year, and the zero-value of CAPIT is only attained asymptotically.

The latter mode is applied in ECONOM, and the depreciation - including interests (interest rate: INTR) that have to be paid normally for a capital - is as follows:

	Actual value of CAPIT	Depreciation incl. interests
year = 1:	1.0	CAPIT • (DEPR + INTR)
year = 2:	(1.0 - DEPR)	CAPIT • (1.0 - DEPR) • (DEPR + INTR)
year = 3:	(1.0 - DEPR) <sup>2</sup>	CAPIT • (1.0 - DEPR) <sup>2</sup> • (DEPR + INTR)
in general:		
year = N:	(1.0 - DEPR) <sup>N-1</sup>	CAPIT • (1.0 - DEPR) <sup>N-1</sup> • (DEPR + INTR)



Time-integrated values - Accommodation costs (option 1), loss-of-income costs

For all periods of time within the first year:

$$TIVA_N = TCAL_N - TCAL_{N-1}$$

For all other periods:

$$TIVA_N = (1 - QRL^{-NTZ_N}) / (1 - QRL^{-1}) - (1 - QRL^{-NTZ_{N-1}}) / (1 - QRL^{-1})$$

where

$TIVA_N$  = time-integrated value (yr), includes duration of each period N and - if necessary - discounting,

$TCAL_N$  = end of period N for all periods within the 1st year, and the other parameters already explained above.

Time-integrated values - Accommodation costs - Option 2

For all periods of time within the first year:

$$TIDP1_N = (DEPRAC + RINTRL)/100 \cdot (TCAL_N - TCAL_{N-1})$$

For all other periods:

$$TIDP1_N = \sum_{NN} (1 - DEPRAC/100)^{NN-1} \cdot (DEPRAC + RINTRL)/100 \cdot QRL^{-NN+1}$$

where

$TIDP1_N$  = time-integrated value (-), includes depreciation and - if necessary - discounting in each year of period N,

$NN$  = years in each period N,

$DEPRAC$  = depreciation rate of accommodation costs (%/yr),

$RINTRL$  = interest rate (%/yr),

and the other parameters already explained above.

Time-integrated values - Lost capital services

The parameter that refers to this cost category is:

$TIDP2_{K,N}$  = time-integrated value (-), includes depreciation and - if necessary - discounting in each year of period N,

where K is the subscript denoting the various capital categories. The calculation of  $TIDP2_{K,N}$  is similar to that of  $TIDP1_N$  - accommodation costs, option 2; therefore, it will not be explained here in detail. The depreciation parameters that are associated with  $TIDP2_{K,N}$  are

$DEPRCA_K$  = depreciation rate lost capital services (K = 1 to 3) (%/yr),

$DEPRLA$  = depreciation rate lost capital services (K = 4: land) (%/yr).

Discount factors - **Decontamination**

This parameter,  $DFDC_N$ , is calculated with the help of the *DISDC* discount rate in the same way as  $DFTR_N$  for transport costs in case of relocation.

## 3.2 SHECOS Submodule

The SHECOS submodule is called by ECONOM if  $ICSHE > 0$  in order to calculate the sheltering costs.

### 3.2.1 Input Information

The following information is used from preceding COSYMA modules:

For the cost calculations of options 1 and 2: information from the INDAT/METEO module (available in the COMMON block):

$POP DAT_{J,I,NS}$  = population in each grid element (J,I),  $J = 1$  to  $JMAX$ ,  $I = 1$  to  $IMAX$ , for each nuclear site  $NS = 1$  to  $NSTMAX$ .

For the cost calculations of option 2: information from an additional data file (read in from NUNITS(07)):

For each nuclear site NS:

$KRE_{J,I}$  = index that assigns each grid element (J,I) to the corresponding economic region NR. The values of KRE range from  $NR = 1$  to  $NRE$ .

For the cost calculations of option 3: information from an additional data file (read in from NUNITS(10)):

For each nuclear site NS:

$ARLOI_{J,I}$  = gross domestic product (GDP) of the area of each grid element (J,I).

This information is processed in the following way (for each nuclear site NS):

Option 1:

$$PSHE1 = \sum_{I=1}^{IMAXSH} \sum_{J=1}^{JMAX} POPDAT_{J,I,NS}$$

Option 2:

For all grid elements (from  $J = 1$  to  $JMAX$  and  $I = 1$  to  $IMAXSH$ ) with identical values  $KRE_{J,I}$  (with  $KRE_{J,I}$  ranging from  $NR = 1$  to  $NRE$ ):

$$PSHE2_{NR} = PSHE2_{KRE_{J,I}} = \sum POPDAT_{J,I,NS}$$

Option 3:

$$CALSH = \sum_{I=1}^{IMAXSH} \sum_{J=1}^{JMAX} ARLOI_{J,I}$$

where

$PSHE1$  = total number of people sheltered (cap),

$IMAXSH$  = index of the outer radius of the sheltering area (-),

$PSHE2_{NR}$  = number of people sheltered in each economic region NR (cap),

$CALSH$  = total GDP, summed up over the sheltering area (M.U./yr).

Note: Sheltering costs are independent of weather sequence L.

### 3.2.2 Cost Calculations

The costs are calculated in the following way:

Option 1:

$$\text{CSHEL} = \text{PSH1} \cdot \text{UCLOI1}_{NS} \cdot (\text{DURSH}/365)$$

Option 2:

$$\text{CSHEL} = \sum_{NR=1}^{NRE} \text{PSH2}_{NR} \cdot \text{UCLOI2}_{NR} \cdot (\text{DURSH}/365)$$

Option 3:

$$\text{CSHEL} = \text{CALSH} \cdot (\text{DURSH}/365) \cdot \text{FUCEC}$$

For the transfer to the TOTCOS submodule:

$$\text{CSHTOT}_{L,NS} = \text{CSHEL}$$

where

$\text{CSHEL}, \text{CSHTOT}_{L,NS}$  = total sheltering costs (M.U.),

$NRE$  = number of economic regions (-),

$\text{UCLOI1}_{NS}$  = site-specific unit costs of loss-of-income (M.U./cap-yr),

$\text{UCLOI2}_{NR}$  = region-specific unit costs of loss-of-income (M.U./cap-yr),

$\text{DURSH} = \text{ITSH}$  = duration of sheltering (days),

$\text{FUCEC}$  = factor to adjust unit costs (-),

and the other parameters already explained above.

### 3.3 EVACOS Submodule

The EVACOS submodule is called by ECONOM if  $\text{ICEVA} > 0$  in order to calculate the evacuation costs.

#### 3.3.1 Input Information

The following information is used from preceding COSYMA modules:

For the cost calculations of all options: information from the AMOUNT module (read in from NUNITS(27)):

For each nuclear site NS, each weather sequence L: POPA, POPB

with

$$\text{PEVA} = \text{POPA} + \text{POPB} = \text{total number of people evacuated (cap).}$$

For the cost calculations of options 2: information from an additional data file (read in from NUNITS(07)):

For each nuclear site NS:

$KRE_{J,I}$  = index that assigns each grid element (J,I) to the corresponding economic region NR. The values of KRE range from NR = 1 to NRE.

KRE is used in the EVAREG subroutine (see Section 3.3.3) to calculate

$PEV_{NR}$  = number of people evacuated in each economic region NR (cap).

For the cost calculations of option 3 (loss-of-income): information from an additional data file (read in from NUNITS(10)):

For each nuclear site NS:

$ARLOI_{J,I}$  = gross domestic product (GDP) of the area of each grid element (J,I).

ARLOI is used in the EVAREG subroutine to calculate

CALEV = total GDP, summed up over the evacuation area (M.U./yr).

### 3.3.2 Cost Calculations

The costs are calculated in the following way:

#### Transport costs

Option 1 = reference option:

$$CEVTRA = PEVA \cdot UEVTRA$$

with

$$UEVTRA = (SPREV \cdot UEVTPR + (1 - SPREV) \cdot UEVTPU) \cdot 2$$

where

CEVTRA = transport costs (M.U.)

UEVTPR = unit costs of private transport (M.U./cap),

UEVTPU = unit costs of public transport (M.U./cap),

SPREV = fraction of population using private transport means (-),

and the other parameters already explained above.

#### Accommodation costs

Option 1:

$$CEVACC = PEVA \cdot UEVAC1_{NS} \cdot DUREV$$

Option 2:

$$CEVACC = \sum_{NR=1}^{NRE} PEV_{NR} \cdot UCACC2_{NR} \cdot (DUREV/365) \cdot ((RINTEV + DEPRAC)/100)$$

where

CEVACC = accommodation costs (M.U.),

$NRE$  = number of economic regions (-),  
 $UEVAC1_{NS}$  = site-specific unit costs of accommodation (M.U./cap-day),  
 $UCACC2_{NR}$  = region-specific unit costs of accommodation (M.U./cap),  
 $DUREV$  =  $ITBACK$  = duration of evacuation (days),  
 $DEPRAC$  = depreciation rate of accommodation costs (%/yr),  
 $RINTEV$  = interest rate (%/yr),  
 and the other parameters already explained above.

### Loss-of-income costs

Option 1:

$$CEVLOI = PEVA \cdot UCLOI1_{NS} \cdot (DUREV/365)$$

Option 2:

$$CEVLOI = \sum_{NR=1}^{NRE} PEV_{NR} \cdot UCLOI2_{NR} \cdot (DUREV/365)$$

Option 3:

$$CEVLOI = CALEV \cdot (DUREV/365) \cdot FUCEC$$

where

$CEVLOI$  = loss-of-income costs (M.U.),  
 $UCLOI1_{NS}$  = site-specific unit costs of loss-of-income (M.U./cap-yr),  
 $UCLOI2_{NR}$  = region-specific unit costs of loss-of-income (M.U./cap-yr),  
 and the other parameters already explained above.

### Total costs

For the transfer to the TOTCOS submodule:

$$\begin{aligned}
 CEVTOT_{L,NS} &= CEVTRA + CEVACC + CEVLOI \\
 &= \text{total evacuation costs (M.U.)}.
 \end{aligned}$$

### 3.3.3 EVAREG Subroutine

The EVAREG subroutine is called by EVACOS within the loops of nuclear sites NS and weather sequences L, if accommodation costs or loss-of-income costs are calculated according to option 2, or if loss-of-income costs are calculated according to option 3.

The following information is used from preceding COSYMA modules:

For the calculations of all options: information from the PROTEC module (read in from NUNITS(26)):

For each weather sequence L, each distance I in the r- $\phi$ -grid: KENNAB<sub>J</sub>, J = 1 to JMAX  
 where

KENNAB<sub>J</sub> = flag that assigns a grid element (J,I) to the evacuation area.

For the calculations of options 2, the following information is used in addition:

$KRE_{J,I}$  = index that assigns each grid element (J,I) to the corresponding economic region NR. The values of KRE range from NR = 1 to NRE.

KRE is read in in EVACOS submodule.

$POP_{J,I,NS}$  = population in each grid element (J,I), J = 1 to JMAX, I = 1 to IMAX, for each nuclear site NS = 1 to NSTMAX.

POP is calculated in the INDAT/METEO module and is available in the COMMON block.

For the calculations of option 3, the parameter

$ARLOI_{J,I}$  = gross domestic product (GDP) of the area of each grid element (J,I)

is used additionally. ARLOI is read in in the EVACOS submodule.

The following data are calculated in EVAREG:

Options 2:

For all grid elements (from J = 1 to JMAX and I = 1 to IMAX) for which

$KEN_{AB,J} = 1$  or  $= 2$ :

For all grid elements (J,I) with identical values  $KRE_{J,I}$

(with  $KRE_{J,I}$  ranging from NR = 1 to NRE):

$PEV_{NR} = PEV_{KRE_{J,I}} = \sum POP_{J,I,NS}$

= number of people evacuated in each economic region NR (cap)

- Option 3:

For all grid elements (from J = 1 to JMAX and I = 1 to IMAX) for

which  $KEN_{AB,J} = 1$  or  $= 2$ :

$CALEV = \sum ARLOI_{J,I}$

= total GDP, summed up over evacuation area (M.U./yr).

### 3.4 RELCOS Submodule

The RELCOS submodule is called by ECONOM if ICREL > 0 in order to calculate the relocation costs.

#### 3.4.1 Input Information

The following information is used from preceding COSYMA modules:

For the cost calculations of all options: information from the AMOUNT module (read in from NUNITS(27)):

For each nuclear site NS, each weather sequence L:

$PREL_N$ , with N = 1 to (NNT + 1) and  $AREL_N$ , with N = 1 to (NNT + 1)

where

$PREL_1$  = total number of people relocated (cap) - (no longer used),

$PREL_{N+1}$  = number of people for which relocation ends in period N (cap),  
 and  
 $AREL_1$  = total area relocated ( $m^2$ ) - (no longer used),  
 $AREL_{N+1}$  = area for which relocation ends in period N ( $m^2$ ).

This information is processed in the following way:

For each period of time  $N = 1$  to  $NNT$

$$PPRL_N = PREL_{N+1}$$

$$PPRLS_N = \sum_{NN=N}^{NNT} PPRL_{NN}$$

$$AARLS_N = \sum_{NN=N}^{NNT} AREL_{NN+1}$$

where

$PPRL_N$  = number of people for which relocation ends in period N (cap),  
 $NNT$  = number of periods considered (-),  
 $PPRLS_N$  = total number of people relocated in each period N (cap),  
 $AARLS_N$  = total area relocated in each period N ( $m^2$ ).

For the cost calculations according to options 2 (except for transport costs): information from an additional data file (read in on NUNITS(07)):

For each nuclear site NS:

$KRE_{J,I}$  = index that assigns each grid element (J,I) to the corresponding economic region NR. The values of KRE range from  $NR = 1$  to  $NRE$ .

KRE is used in the RELREG subroutine (see Section 3.4.3) to calculate

$PRL_{NR,N}$  = number of people in each economic region NR, for which relocation ends in period N (cap),

$PRLS_{NR,N}$  = total number of people relocated in each economic region NR in period N (cap),

$ARL_{NR,N}$  = area in each economic region NR, for which relocation ends in period N ( $m^2$ ),

$ARLS_{NR,N}$  = total area relocated in each economic region NR in period N ( $m^2$ ).

For the cost calculations according to option 3 (loss-of-income): information from an additional data file (read in from NUNITS(10)):

For each nuclear site NS:

$ARLOI_{J,I}$  = gross domestic product (GDP) of the area of each grid element (J,I).

ARLOI is used in the RELREG subroutine to calculate

$CALRL_N$  = GDP, summed up over area in which relocation ends in period N (M.U./yr),

$CALRLS_N$  = GDP, summed up over total area relocated of period N (M.U./yr),

### 3.4.2 Cost Calculations

The costs are calculated in the following way:

#### Transport (TRA) costs

- Option 1

"TYPE A" costs

Period N = 1:

$$\begin{aligned} \text{CRLTR}_1 &= \\ &\quad \text{Costs of moving-away:} \\ &\quad \text{PPRLS}_1 \cdot \text{URLTRA} \\ &+ \\ &\quad \text{Costs of return:} \\ &\quad \text{PPRL}_1 \cdot \text{URLTRA} \end{aligned}$$

Periods N = 2 to NTR (return costs only):

$$\text{CRLTR}_N = \text{PPRL}_N \cdot \text{URLTRA} \cdot \text{DFTR}_N$$

with

$$\text{URLTRA} = (\text{SPRRL} \cdot \text{URLTPR} + (1 - \text{SPRRL}) \cdot \text{URLTPU})$$

"TYPE C" costs

$$\text{CRLTRZ}_N =$$

$$\begin{aligned} &\quad \text{Costs of moving-away (for periods N = 1 to NNT):} \\ &\quad \text{PPRL}_N \cdot \text{URLTRA} \\ &+ \\ &\quad \text{Costs of return (for periods N = 1 to NTR):} \\ &\quad \text{PPRL}_N \cdot \text{URLTRA} \cdot \text{DFTR}_N \end{aligned}$$

- Option 2

"TYPE A" costs and "TYPE C" costs

$$\text{CRLTR}_1 = \text{CRLTRZ}_1 = \text{PPRLS}_1 \cdot \text{URLTRA} \cdot 2$$

where

$\text{CRLTR}_N$  = TRA costs "TYPE A" in each period N (M.U.),

$\text{CRLTRZ}_N$  = TRA costs "TYPE C" in each period N (M.U.),

NTR = index of last period for the calculation of TRA costs, calculated in the DISCO subroutine,

$\text{URLTPR}$  = unit costs of private transport (M.U./cap),

$\text{URLTPU}$  = unit costs of public transport (M.U./cap),

$\text{SPRRL}$  = fraction of population using private transport means (-),



$DFTR_N$  = discount factor (-), calculated in the DISCO subroutine  
(see Section 3.1.1),

and the other parameters already explained above.

### Accommodation (ACC) costs

- Option 1

"TYPE A" costs (for periods  $N = 1$  to  $NAC$ ):

$$CRLAC_N = PPRLS_N \cdot UCACC1_{NS} \cdot TIVA_N$$

"TYPE C" costs (for periods  $N = 1$  to  $NNT$ ):

$$CRLACZ_N = \sum_{NN=1}^N PPRL_N \cdot UCACC1_{NS} \cdot TIVA_{NN}$$

- Option 2

"TYPE A" costs (for periods  $N = 1$  to  $NAC$ ):

$$CRLAC_N = \sum_{NR=1}^{NRE} PRLS_{NR,N} \cdot UCACC2_{NR} \cdot TIDP1_N$$

"TYPE C" costs (for periods  $N = 1$  to  $NNT$ ):

$$CRLACZ_N = \sum_{NN=1}^N \sum_{NR=1}^{NRE} PRL_{NR,N} \cdot UCACC2_{NR} \cdot TIDP1_{NN}$$

where

$CRLAC_N$  = ACC costs "TYPE A" in each period  $N$  (M.U.),

$CRLACZ_N$  = ACC costs "TYPE C" in each period  $N$  (M.U.),

$NAC$  = index of last period for the calculation of ACC costs,  
calculated in the DISCO subroutine,

$NN$  = index of periods,  $NN = 1$  to  $N$ ,

$NRE$  = number of economic regions (-),

$UCACC1_{NS}$  = site-specific unit costs of ACC (M.U./cap-yr),

$UCACC2_{NR}$  = region-specific unit costs of ACC (M.U./cap),

$TIVA_{N(NN)}$  = time-integrated value (yr), includes duration of each period  
 $N(NN)$  and discounting, calculated in the DISCO subroutine  
(see Section 3.1.1),

$TIDP1_{N(NN)}$  = time-integrated value (-), includes depreciation and discounting  
in each year of period  $N(NN)$ , calculated in the DISCO subroutine,

and the other parameters already explained above.

### Loss-of-income (LOI) costs

- Option 1

"TYPE A" costs (for periods  $N = 1$  to  $NAC$ ):

$$CRLLI_N = PPRLS_N \cdot UCLOI1_{NS} \cdot TIVA_N$$

"TYPE C" costs (for periods N = 1 to NNT):

$$CRLIZ_N = \sum_{NN=1}^N PPRL_N \cdot UCLO1_{NS} \cdot TIVA_{NN}$$

- Option 2

"TYPE A" costs (for periods N = 1 to NAC):

$$CRLI_N = \sum_{NR=1}^{NRE} PRLS_{NR,N} \cdot UCLO2_{NR} \cdot TIVA_N$$

"TYPE C" costs (for periods N = 1 to NNT):

$$CRLIZ_N = \sum_{NN=1}^N \sum_{NR=1}^{NRE} PRL_{NR,N} \cdot UCLO2_{NR} \cdot TIVA_{NN}$$

- Option 3

"TYPE A" costs (for periods N = 1 to NAC):

$$CRLI_N = CALRLS_N \cdot TIVA_N \cdot FUCEC$$

"TYPE C" costs (for periods N = 1 to NNT):

$$CRLIZ_N = \sum_{NN=1}^N CALRL_N \cdot TIVA_{NN} \cdot FUCEC$$

where

$CRLI_N$  = LOI costs "TYPE A" in each period N (M.U.),

$CRLIZ_N$  = LOI costs "TYPE C" in each period N (M.U.),

$UCLO1_{NS}$  = site-specific unit costs of LOI (M.U./cap-yr),

$UCLO2_{NR}$  = region-specific unit costs of LOI (M.U./cap-yr),

$FUCEC$  = factor to adjust unit costs (-),

and the other parameters already explained above.

### Costs of lost capital services (LCS)

- Option 1

"TYPE A" costs (for periods N = 1 to NNT):

$$CRLLC_N = \sum_{K=1}^3 (PPRLS_N \cdot UCCAP1_{NS,K} \cdot TIDP2_{K,N})$$

$$+ AARLS_N \cdot UCLAN1_{NS} \cdot TIDP2_{4,N}$$

"TYPE C" costs (for periods N = 1 to NNT):

$$CRLLCZ_N = \sum_{NN=1}^N \left( \sum_{K=1}^3 (PPRL_N \cdot UCCAP1_{NS,K} \cdot TIDP2_{K,NN}) \right.$$

$$\left. + AREL_{N+1} \cdot UCLAN1_{NS} \cdot TIDP2_{4,NN} \right)$$

- Option 2

"TYPE A" costs (for periods  $N = 1$  to  $NNT$ ):

$$\begin{aligned} \text{CRLLC}_N &= \sum_{NR=1}^{NRE} \left( \sum_{K=1}^3 (\text{PRLS}_{NR,N} \cdot \text{UCCAP2}_{NR,K} \cdot \text{TIDP2}_{K,N}) \right. \\ &\quad \left. + \text{ARLS}_{NR,N} \cdot \text{UCLAN2}_{NR} \cdot \text{TIDP2}_{4,N} \right) \end{aligned}$$

"TYPE C" costs (for periods  $N = 1$  to  $NNT$ ):

$$\begin{aligned} \text{CRLLCZ}_N &= \sum_{NN=1}^N \left( \sum_{NR=1}^{NRE} \left( \sum_{K=1}^3 (\text{PRL}_{NR,N} \cdot \text{UCCAP2}_{NR,K} \cdot \text{TIDP2}_{K,NN}) \right. \right. \\ &\quad \left. \left. + \text{ARL}_{NR,N} \cdot \text{UCLAN2}_{NR} \cdot \text{TIDP2}_{4,NN} \right) \right) \end{aligned}$$

where

- $\text{CRLLC}_N$  = LCS costs "TYPE A" in each period  $N$  (M.U.),
- $\text{CRLLCZ}_N$  = LCS costs "TYPE C" in each period  $N$  (M.U.),
- $\text{UCCAP1}_{NS,K}$  = site-specific unit costs of LCS ( $K = 1$ : non-residential,  $K = 2$ : housing,  $K = 3$ : consumer durables) (M.U./cap),
- $\text{UCLAN1}_{NS}$  = site-specific unit costs of LCS (land) (M.U./m<sup>2</sup>),
- $\text{UCCAP2}_{NR,K}$  = region-specific unit costs of LCS ( $K = 1$  to  $3$ ) (M.U./cap),
- $\text{UCLAN2}_{NR}$  = region-specific unit costs of LCS (land) (M.U./m<sup>2</sup>),
- $\text{TIDP2}_{K,N(NN)}$  = time-integrated value (-), includes depreciation and discounting in each year of period  $N(NN)$ , calculated in the DISCO subroutine (see Section 3.1.1),

and the other parameters already explained above.

**Total costs**

"TYPE A" costs (for periods  $N = 1$  to  $NNT$ ):

$$\text{CRLTO}_N = \text{CRLTR}_N + \text{CRLAC}_N + \text{CRLLI}_N + \text{CRLLC}_N$$

"TYPE B" costs (for periods  $N = 1$  to  $NNT$ ):

$$\begin{aligned} \text{CRLTRS}_N &= \text{CRLTRS}_{N-1} + \text{CRLTR}_N \\ (\text{CRLACS}_N, \text{CRL LIS}_N, \text{CRL LCS}_N &\text{ are calculated accordingly}) \\ \text{CRLTOS}_N &= \text{CRLTOS}_{N-1} + \text{CRLTO}_N \end{aligned}$$

"TYPE C" costs (for periods  $N = 1$  to  $NNT$ ):

$$\text{CRLTOZ}_N = \text{CRLTRZ}_N + \text{CRLACZ}_N + \text{CRL LIZ}_N + \text{CRL LCZ}_N$$

For the transfer to the TOTCOS submodule:

$$\text{CRLTOT}_{L,NS} = \text{CRLTOS}_{NNT}$$

where

$CRLTO_N$  = relocation costs "TYPE A" in each period N (M.U.),

$CRLTRS_N$  = TRA costs "TYPE B" in each period N (M.U.),

( $CRLACS_N$ ,  $CRL LIS_N$ ,  $CRL LCS_N$  accordingly)

$CRLTOS_N$  = relocation costs "TYPE B" in each period N (M.U.),

$CRLTOZ_N$  = relocation costs "TYPE C" in each period N (M.U.),

$CRLTOT_{L,NS}$  = total relocation costs (M.U.),

and the other parameters already explained above.

### 3.4.3 RELREG Subroutine

The RELREG Subroutine is called by RELCOS within the loops of nuclear sites NS and weather sequences L, if accommodation costs, loss-of-income costs or costs of lost capital services are calculated according to option 2, or if loss-of-income costs are calculated according to option 3.

The following information is used from preceding COSYMA modules:

For the calculations of all options: information from the PROTEC module (read in from NUNITS(19)):

For each weather sequence L, each distance l in the  $r-\phi$ -grid:  $KENNC_J$ ,  $J = 1$  to  $JMAX$

where

$KENNC_J$  = flag that assigns a grid element (J,l) to the relocation area, the value of  $KENNC_J$  is the index of the period in which relocation ends.

For the calculations of options 2, the following information is used additionally:

$KRE_{J,l}$  = index that assigns each grid element (J,l) to the corresponding economic region NR. The values of KRE range from  $NR = 1$  to  $NRE$ .

KRE is read in in the RELCOS submodule.

$POPDAT_{J,l,NS}$  = population in each grid element (J,l),  $J = 1$  to  $JMAX$ ,  $l = 1$  to  $IMAX$ , for each nuclear site  $NS = 1$  to  $NSTMAX$ ,

$FLAND_{J,l,NS}$  = land area of each grid element (J,l),  $J = 1$  to  $JMAX$ ,  $l = 1$  to  $IMAX$ , for each nuclear site  $NS = 1$  to  $NSTMAX$ .

POPDAT and FLAND are calculated in the INDAT/METEO module and are available in the COMMON block.

For the calculations of option 3, the parameter

$ARLOI_{J,l}$  = gross domestic product (GDP) of the area of each grid element (J,l) is used additionally. ARLOI is read in in the RELCOS submodule.

The following data are calculated in RELREG:

- Options 2:

For all grid elements (from  $J = 1$  to  $JMAX$  and  $I = 1$  to  $IMAX$ ) for which  $KENNC_J > 0$ :

For all grid elements (J,I) with identical values  $KRE_{J,I}$  and  $KENNC_J$

(with  $KRE_{J,I}$  ranging from  $NR = 1$  to  $NRE$  and  $KENNC_J$  ranging from  $N = 1$  to  $NNT$ ):

$$PRL_{NR,N} = PRL_{KRE_{J,I}, KENNC_J} = \sum POPDAT_{J,I,NS}$$

$$ARL_{NR,N} = ARL_{KRE_{J,I}, KENNC_J} = \sum FLAND_{J,I,NS}$$

For all economic regions  $NR = 1$  to  $NRE$ , all periods  $N = 1$  to  $NNT$

$$PRLS_{NR,N} = \sum_{NN=N}^{NNT} PRL_{NR,N}$$

$$ARLS_{NR,N} = \sum_{NN=N}^{NNT} ARL_{NR,N}$$

where

$PRL_{NR,N}$  = number of people in each economic region  $NR$ , for which relocation ends in period  $N$  (cap),

$PRLS_{NR,N}$  = total number of people relocated in each economic region  $NR$  in period  $N$  (cap),

$ARL_{NR,N}$  = area in each economic region  $NR$ , for which relocation ends in period  $N$  ( $m^2$ ),

$ARLS_{NR,N}$  = total area relocated in each economic region  $NR$  in period  $N$  ( $m^2$ ).

- Option 3:

For all grid elements (from  $J = 1$  to  $JMAX$  and  $I = 1$  to  $IMAX$ ) for which  $KENNC_J > 0$ :

For all grid elements (J,I) with identical values  $KENNC_J$

(with  $KENNC_J$  ranging from  $N = 1$  to  $NNT$ ):

$$CALRL_N = CALRL_{KENNC_J} = \sum ARLOI_{J,I}$$

For all periods  $N = 1$  to  $NNT$

$$CARLS_N = \sum_{NN=N}^{NNT} CALRL_N$$

where

$CALRL_N$  = GDP, summed up over area in which relocation ends in period  $N$  (M.U./yr),

$CARLS_N$  = GDP, summed up over total area relocated of period  $N$  (M.U./yr).

### 3.5 DECCOS Submodule

The DECCOS submodule is called by ECONOM if ICDEC > 0 in order to calculate the decontamination costs.

### 3.5.1 Input Information

The following information is used from preceding COSYMA modules:

For the cost calculations of options 1 and 2: information from the AMOUNT module (read in from NUNITS(27)):

For each weather sequence L:  $ADEC_N$ , with  $N = 1$  to  $(NNT + 1)$

where

$ADEC_1$  = total decontamination area ( $m^2$ ) - (no longer used),

$ADEC_{N+1}$  = decontamination area in period N ( $m^2$ ),

$NNT$  = number of periods considered (-).

For the cost calculations of option 2: additional information from the AMOUNT module (read in from NUNITS(27)):

For each nuclear site NS, each weather sequence L:  $PDEC_N$ ,  $N = 1$  to  $(NNT + 1)$ ,

where

$PDEC_1$  = number of people living in  $ADEC_1$  (cap) - (no longer used),

$PDEC_{N+1}$  = number of people living in  $ADEC_{N+1}$  (cap).

### 3.5.2 Cost Calculations

The costs are calculated in the following way:

- Option 1:

"TYPE A" costs (for periods  $N = 1$  to  $NNT$ ):

$$CDEC_N = ADEC_{N+1} \cdot UDECA_N \cdot DFDC_N \cdot FRUR_{NS}$$

- Option 2:

"TYPE A" costs (for periods  $N = 1$  to  $NNT$ ):

$$CDEC_N = ADEC_{N+1} \cdot UDECA_N \cdot DFDC_N \cdot FRUR_{NS} \\ + PDEC_N \cdot UDECP_N \cdot DFDC_N$$

- Options 1 and 2:

"TYPE B" costs (for periods  $N = 1$  to  $NNT$ ):

$$CDECS_N = CDECS_{N-1} + CDEC_N$$

For the transfer to the TOTCOS submodule:

$$CDCTOT_{L,NS} = CDECS_{NNT}$$

where

$CDEC_N$  = decontamination costs "TYPE A" in each period N (M.U.),

$CDECS_N$  = decontamination costs "TYPE B" in each period N (M.U.),

$UDECA_N$  = area-specific unit costs of decontamination (M.U./ $m^2$ ),

$UDECP_N$  = per-capita-specific unit costs of decontamination (M.U./cap),

$DFDC_N$  = discount factor (-), calculated in the DISCO subroutine (see Section 3.1.1),  
 $FRUR_{NS}$  = fraction of rural/total area to be decontaminated, to be used in option 2, for option 1:  $FRUR_{NS} = 1.0$ .  
 $CDCTOT_{L,NS}$  = total decontamination costs (M.U.),  
 and the other parameters already explained above.

### 3.6 FOBCOS Submodule

The FOBCOS submodule is called by ECONOM if ICFOB > 0 in order to calculate the food ban costs.

#### 3.6.1 Input Information

The information used from preceding COSYMA modules is from the AMOUNT module (read in from NUNITS(27)):

For each nuclear site NS, each weather sequence L:

$QUANT_{IEC,N}$ , for IEC = 1 to NECO, and N = 1 to NBAN

where

$QUANT_{IEC,1}$  = total amount of food product type IEC - (no longer used),

$QUANT_{IEC,N}$  = yearly amount of food product type IEC for which food ban ends in period N (for N = 2 to N = NBAN),

NECO = number of food product types (-),

NBAN = number of periods (-).

The sequence of food products and the respective units of QUANT are determined by the agricultural production grids. The default sequence and the units used in this version of COSYMA are:

IEC = 1: milk (l/yr), IEC = 2: livestock (heads/yr), IEC = 3: crop area (km<sup>2</sup>).

This information is processed in the following way:

For each food product type IEC, each period N:

$$QUANTS_{IEC,N} = \sum_{NN=N}^{MBAN} QUANT_{IEC,NN+1}$$

= yearly amount of food product type IEC banned in each period N

with

$$MBAN = NBAN - 1$$

Note: The originally defined time-frame in the ingestion module includes  $N = \text{NBAN}$  periods of time with the value  $T = 0$  assigned to the first period. This period is omitted in calculating economic consequences; therefore, in *ECONOM* the number of periods is reduced by 1 which gives  $\text{MBAN} = \text{NBAN} - 1$ .

### 3.6.2 Cost Calculations

The costs are calculated in the following way:

#### Costs of lost food

"TYPE A" costs

For periods  $N = 1$  to  $\text{NAG}$ , for food product types  $\text{IEC} = 1$  to  $\text{NECO}$

$$\text{CFBPR}_{\text{IEC},N} = \text{QUANTS}_{\text{IEC},N} \cdot \text{UFBPR}_{K,\text{IEC}} \cdot \text{COFAPR}_{\text{IEC}} \cdot \text{TIVAG}_N$$

"TYPE C" costs

For periods  $N = 1$  to  $\text{MBAN}$ , for food product types  $\text{IEC} = 1$  to  $\text{NECO}$

$$\text{CFBPRZ}_{\text{IEC},N} = \sum_{\text{NN}=1}^N \text{QUANT}_{\text{IEC},N+1} \cdot \text{UFBPR}_{K,\text{IEC}} \cdot \text{COFAPR}_{\text{IEC}} \cdot \text{TIVAG}_{\text{NN}}$$

where

$\text{CFBPR}_{\text{IEC},N}$  = costs of lost food "TYPE A" for  $N$ ,  $\text{IEC}$  (M.U.),

$\text{CFBPRZ}_{\text{IEC},N}$  = costs of lost food "TYPE C" for  $N$ ,  $\text{IEC}$  (M.U.),

$\text{NAG}$  = index of the last period for the calculation of costs of lost food, calculated in the *FOBDIS* subroutine,

$\text{NN}$  = index of periods,  $\text{NN} = 1$  to  $N$ ,

$\text{UFBPR}_{K,\text{IEC}}$  = unit costs of lost food for  $\text{IEC}$ ,  $K$  (M.U./kg),  
Note:  $K = 1$  is used for all periods that fall into the first year,  
 $K = 2$  for all periods beyond the first year,

$\text{COFAPR}_{\text{IEC}}$  = conversion factor of each food product type  $\text{IEC}$   
(from unit quantities of the production grids into kg),

$\text{TIVAG}_{\text{N}(\text{NN})}$  = time-integrated value (yr), includes duration of each period  $\text{N}(\text{NN})$  and discounting, calculated in the *FOBDIS* subroutine (see Section 3.6.3),

and the other parameters already explained above.

#### Costs of lost agricultural capital (LAC)

"TYPE A" costs

For periods  $N = 1$  to  $\text{MBAN}$ , for food product types  $\text{IEC} = 1$  to  $\text{NECO}$

$$\begin{aligned} \text{CFBLC}_{\text{IEC},N} &= \sum_{K=1}^2 \text{QUANTS}_{\text{IEC},N} \cdot \text{UFBLC}_{K,\text{IEC}} \cdot \text{COFAPR}_{\text{IEC}} \cdot \text{TIDP3}_{K,N} \\ &+ \text{QUANTS}_{\text{IEC},N} \cdot \text{UFBLA} \cdot \text{COFALA}_{\text{IEC}} \cdot \text{TIDP3}_{3,N} \end{aligned}$$



"TYPE C" costs

For periods  $N = 1$  to MBAN, for food product types  $IEC = 1$  to NECO

$$CFBLCZ_{IEC,N} = \sum_{NN=1}^N \left( \sum_{K=1}^2 \text{QUANT}_{IEC,N+1} \cdot UFBL C_{K,IEC} \cdot COFAPR_{IEC} \cdot TIDP3_{K,NN} \right) \\ + \text{QUANT}_{IEC,N+1} \cdot UFBLA \cdot COFALA_{IEC} \cdot TIDP3_{3,NN}$$

where

$CFBLC_{IEC,N}$  = costs of LAC "TYPE A" for N, IEC (M.U.),

$CFBLCZ_{IEC,N}$  = costs of LAC "TYPE C" for N, IEC (M.U.),

$UFBL C_{K,IEC}$  = unit costs LAC for IEC, K (M.U./(kg/yr)),  
(K = 1: non-residential, K = 2: buildings),

$UFBLA$  = unit costs LAC (land) (M.U./km<sup>2</sup>),

$COFALA_{IEC}$  = conversion factor of each food product type IEC  
(from unit quantities of production grids into km<sup>2</sup>),

$TIDP3_{K,N(NN)}$  = time-integrated value (-), includes depreciation and discounting  
in each year of period N(NN), calculated in the FOBDIS  
subroutine, (see Section 3.6.3),

and the other parameters already explained above.

### Costs of food disposal

"TYPE A" costs

For periods N within the first year, for food product types  $IEC = 1$  to NECO

$$CFBDS_{IEC,N} = \text{QUANTS}_{IEC,N} \cdot UFBDS_{IEC} \cdot COFAPR_{IEC} \cdot TIVAG_N$$

"TYPE C" costs

For periods  $N = 1$  to MBAN, for periods NN within the first year,

for food product types  $IEC = 1$  to NECO

$$CFBDSZ_{IEC,N} = \sum_{NN=1}^N \text{QUANT}_{IEC,N+1} \cdot UFBDS_{IEC} \cdot COFAPR_{IEC} \cdot TIVAG_{NN}$$

where

$CFBDS_{IEC,N}$  = food disposal costs "TYPE A" for N, IEC (M.U.),

$CFBDSZ_{IEC,N}$  = food disposal costs "TYPE C" for N, IEC (M.U.),

$UFBDS_{IEC}$  = unit costs of food disposal for IEC (M.U./kg),

and the other parameters already explained above.

### Total costs

$$CFBTPR = \sum_{N=1}^{MBAN} \sum_{IEC=1}^{NECO} CFBPR_{IEC,N}$$

$$CFBTLC = \sum_{N=1}^{MBAN} \sum_{IEC=1}^{NECO} CFBLC_{IEC,N}$$

$$CFBTDS = \sum_{N=1}^{MBAN} \sum_{IEC=1}^{NECO} CFBDS_{IEC,N}$$

For periods  $N = 1$  to  $MBAN$ , for food product types  $IEC = 1$  to  $NECO$

$$CFBIC_{IEC,N} = CFBPR_{IEC,N} + CFBLC_{IEC,N} + CFBDS_{IEC,N}$$

$$CFBICZ_{IEC,N} = CFBPRZ_{IEC,N} + CFBLCZ_{IEC,N} + CFBDSZ_{IEC,N}$$

For periods  $N = 1$  to  $MBAN$

$$CFBTO_N = \sum_{IEC=1}^{NECO} CFBIC_{IEC,N}$$

$$CFBTOZ_N = \sum_{IEC=1}^{NECO} CFBICZ_{IEC,N}$$

"TYPE B" costs

For periods  $N = 1$  to  $MBAN$ , for food product types  $IEC = 1$  to  $NECO$

$$CFBICS_{IEC,N} = CFBICS_{IEC,N-1} + CFBIC_{IEC,N}$$

For periods  $N = 1$  to  $MBAN$

$$CFBTOS_N = CFBTOS_{N-1} + CFBTO_N$$

For the transfer to the TOTCOS submodule:

$$CFBTOT_{L,NS} = CFBTOS_{MBAN}$$

where

CFBTPR = total costs of lost food (M.U.),

CFBTLC = total costs of lost agricultural capital (M.U.),

CFBTDS = total food disposal costs (M.U.),

CFBIC<sub>IEC,N</sub> = total costs "TYPE A" for periods N, product types IEC (M.U.),

CFBICZ<sub>IEC,N</sub> = total costs "TYPE C" for periods N, product types IEC (M.U.),

CFBTO<sub>N</sub> = total costs "TYPE A" for periods N (M.U.),

CFBTOZ<sub>N</sub> = total costs "TYPE C" for periods N (M.U.),

CFBICS<sub>IEC,N</sub> = total costs "TYPE B" for periods N, product types IEC (M.U.),

CFBTOS<sub>N</sub> = total costs "TYPE B" for periods N (M.U.),

CFBTOT<sub>L,NS</sub> = total food ban costs (M.U.).

### 3.6.3 FOBDIS Subroutine

The FOBDIS subroutine is called by FOBCOS in order to precalculate the following parameters that are used for the calculation of food ban costs:

NAG = index of the last period for the calculation of costs of lost food (this value is determined by the user-defined recovery time *NTRAG*),

$TIVAG_{NY}$  = time-integrated value for each period NY  
used for the calculation of the costs of lost food  
and of food disposal,

$TIDP3_{K,NY}$  = time-integrated value for each period NY  
used for the calculation of the costs of lost agricultural capital.

The calculational procedures for  $TIVAG_{NY}$  and  $TIDP3_{K,NY}$  are the same as for the respective parameters described in the DISCO subroutine (see Section 3.1.1), and, therefore, are not explained here in more detail.

### 3.7 EHECOS Submodule

The EHECOS submodule is called by ECONOM if  $ICEHE > 0$  in order to calculate the costs of early health effects.

#### 3.7.1 Input Information

The following information is used from preceding COSYMA modules:

For the cost calculations of both options: information from the COLLEC module (read in from NUNITS(28) for the subsystem NE and from NUNITS(48) for the subsystem NL):

For  $MOR = IMOR$  to 2, for each nuclear site NS, for each weather sequence L:

$FGESOG_{NOG}$  = number of health effects for each type  $NOG = 1$  to 5,

$FGES$  = total number of health effects (sum over all types  
 $NOG = 1 + 2 + 3 + 5$ ).

**Note:** In the default procedure, the preceding program units of COSYMA dealing with early health effects normally calculate (1) non-fatal effects (morbidity,  $MOR = 1$ ) and (2) fatal effects (mortality,  $MOR = 2$ ) independently of each other. This is done by setting the steering parameter  $IMOR = 1$ . With the input value  $IMOR = 2$ , the calculations can be reduced to fatal effects only. This procedure has to be applied also in the ECONOMICS module.

In the case of morbidity,  $FGES$  is the sum of all single values  $FGESOG_{NOG}$  for  $NOG = 1 + 2 + 3 + 5$ ; whereas in case of mortality  $FGES$  may be lower than the sum of all single values. This is true, because multiple counting is excluded for an individual suffering from more than one type of fatal health effect. Therefore, in case of mortality the single values  $FGESOG_{NOG}$  are adjusted to the total value  $FGES$  in order to avoid double counting of costs.

### 3.7.2 Cost Calculations

The costs are calculated in the following way:

- Option 1:

For MOR = IMOR to 2, for each type NOG = 1 to 5

$$CEHE_{NOG} = FGESOG_{NOG} \cdot UEHSV_{NOG,MOR}$$

$$CEHSEV = \sum_{NOG=1}^5 CEHE_{NOG}$$

For the transfer to the TOTCOS submodule:

$$CEHTOT_{L,NS} = \sum_{MOR=IMOR}^2 CEHSEV$$

where

$CEHE_{NOG}$  = health effect costs for each type NOG (M.U.),

$CEHSEV$  = total health effect costs - option 1 (M.U.),

$CEHTOT_{L,NS}$  = total early health effect costs (morbidity **and** mortality) (M.U.),

$UEHSV_{NOG,MOR}$  = unit costs (total) for each type NOG (M.U./case),

and the other parameters already explained above.

- Option 2:

For MOR = IMOR to 2, for each type NOG = 1 to 5

$$CEH1_{NOG} = FGESOG_{NOG} \cdot UEHTR_{NOG,MOR}$$

$$CEH2_{NOG} = FGESOG_{NOG} \cdot UCLOE \cdot DFEH_{NOG}$$

$$CEHE_{NOG} = CEH1_{NOG} + CEH2_{NOG}$$

$$CEHTRE = \sum_{NOG=1}^5 CEH1_{NOG}$$

$$CEHLOS = \sum_{NOG=1}^5 CEH2_{NOG}$$

$$CEHHUC = CEHTRE + CEHLOS$$

with

$$DFEH_{NOG} = (1 - QEH^{-DUREH_{NOG,MOR}}) / (1 - QEH^{-1})$$

and

$$QEH = 1 + (DISHE/100)$$

For the transfer to the TOTCOS submodule:

$$CEHTOT_{L,NS} = \sum_{MOR=IMOR}^2 CEHHUC$$

where

$CEH1_{NOG}$  = medical treatment costs for each type NOG (M.U.),

$CEH2_{NOG}$  = losses-to-economy costs for each type NOG (M.U.),  
 $CEHE_{NOG}$  = health effect costs for each type NOG (M.U.),  
 $CEHTRE$  = total medical treatment costs (M.U.),  
 $CEHLOS$  = total losses-to-economy costs (M.U.),  
 $CEHHUC$  = total health effect costs - option 2 (M.U.),  
 $UEHTR_{NOG,MOR}$  = unit costs (medical treatment) for each type NOG (M.U./case),  
 $UCLOE$  = unit costs of losses to the economy (M.U./case-yr),  
 $DFEH_{NOG}$  = time-integrated value - includes  $DUREH_{NOG,MOR}$  and discounting (yr),  
 $DUREH_{NOG,MOR}$  = periods for calculation of losses-to-economy costs (yr),  
 $DISHE$  = discount rate (%/yr),  
 and the other parameters already explained above.

**Note:** All costs (except for  $CEHTOT_{L,NS}$ ) are calculated separately for morbidity (MOR = 1) and mortality (MOR = 2).

### 3.8 LHECOS Submodule

The LHECOS submodule is called by ECONOM if  $ICLHE > 0$  in order to calculate the costs of late health effects.

#### 3.8.1 Input Information

The following information is used from preceding COSYMA modules:

For the cost calculations of all options: information from the COLLEC module (read in from NUNITS(28)):

For the living generations  $LF = 1$ , for each nuclear site NS,  
for each weather sequence L:

$FGESOG_{NOG}$  = number of fatal cancers for each type NOG = 1 to 11  
and number of hereditary effects, NOG = 12

From this set of values, only that of hereditary effects is used:

$HER_{L,NS}$  =  $FGESOG_{12}$

If no information for  $LF = 1$  is available from COLLEC, i.e. if the agricultural production method is used in the ingestion model (see /7/),

$HER_{L,NS}$  is set = 0.

For the sum of the living and the following generations  $LF = 3$ ,  
for each nuclear site NS, for each weather sequence L:

$FGESOG_{NOG}$  = number of fatal cancers for each type  $NOG = 1$  to  $11$   
and number of hereditary effects,  $NOG = 12$

$FGES$  = total number of fatal cancers (sum over  $NOG = 1$  to  $NOG = 11$ ).

The data for fatal cancers are processed in the following way:

An adjustment of the single values of each fatal cancer type  $FGESOG_{NOG}$  to the total value  $FGES$  is made, as  $FGES$  may be lower than the sum of the single values. This is true, because multiple counting is excluded for an individual suffering from more than one fatal cancer.

A breakdown of each single value  $FGESOG_{NOG}$  into a time-frame  $IOBS_N$  with 10 periods  $N = 1$  to  $10$ , covering a range from 0 to 200 years, is made with the help of a special time function  $TIMFCT_{N,NOG}$  (see below).

For each fatal cancer type  $FGESOG_{NOG}$  the corresponding non-fatal value is calculated with the help of a correction factor for cancer incidence  $ORBID_{NOG}$ .

Finally, in order to reduce the amount of economic input values, the cancer types "stomach, colon, liver, pancreas" are condensed to one new type called "GI-tract".

In this way, from each original value  $FGESOG_{NOG}$  ( $NOG = 1$  to  $NOG = 11$ ) a set of values  $GESOG_{N,NOG,MOR}$  is calculated with periods  $N = 1$  to  $N = 10$ , health effect types  $NOG = 1$  to  $NOG = 8$ , and for morbidity ( $MOR = 1$ ) and mortality ( $MOR = 2$ ).

The following additional data are included in the LHECOS submodule for the calculation of late health effect costs:

$IOBS_N$ , a time-frame with 10 periods  $N$  (yr),

DATA IOBS /5,10,20,30,40,50,70,90,150,200/

$TIMFCT_{N,NOG}$ , a time function which provides a breakdown of occurrence of each cancer type  $NOG = 1$  to  $11$  into the periods defined by  $IOBS_N$  (%),

DATA TIMFCT/

1	3.33,13.85,24.42,17.50,12.12, 8.22, 9.74, 5.63, 4.87, 0.32,
2	0.00, 9.04,21.13,23.36,15.65,10.23,11.03, 5.02, 4.23, 0.31,
3	0.00, 0.28, 1.46, 3.40, 7.34,12.26,31.29,23.26,18.96, 1.75,
4	0.00, 1.33, 4.01, 6.03, 9.02,12.88,32.04,19.85,13.54, 1.30,
5	0.00, 1.04, 3.38, 5.05, 7.43,10.50,28.34,23.66,18.60, 2.00,
6	0.00, 1.30, 4.10, 5.60, 8.30,11.25,29.27,22.10,16.38, 1.70,
7	0.00, 0.85, 3.22, 5.73, 9.11,12.81,30.37,20.34,16.02, 1.55,
8	0.00, 1.14, 3.65, 5.24, 7.75,10.90,28.62,22.64,18.18, 1.88,
9	0.00, 0.60, 3.21, 6.08, 9.56,14.52,39.60,22.80, 3.30, 0.33,

1 0.00, 1.48, 4.82, 6.56, 8.96, 11.60, 28.27, 20.17, 16.56, 1.58,  
 2 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00/

TLILO<sub>N,NOG</sub>, number of years of life lost in each period N for each cancer type  
 NOG = 1 to 8 (yr),

DATA TLILO /  
 1 29.0, 24.0, 19.0, 16.0, 13.0, 10.0, 6.0, 1.5, 0.0, 0.0,  
 2 31.0, 29.0, 24.0, 19.0, 14.0, 9.0, 4.0, 0.0, 0.0, 0.0,  
 3 19.0, 14.0, 8.0, 4.0, 2.0, 0.5, 0.2, 0.1, 0.0, 0.0,  
 4 12.0, 11.0, 10.0, 7.0, 5.0, 3.0, 1.5, 0.3, 0.0, 0.0,  
 5 13.0, 12.0, 10.0, 7.0, 5.0, 3.0, 2.0, 0.4, 0.0, 0.0,  
 6 19.0, 13.0, 7.0, 3.0, 2.0, 1.0, 0.3, 0.0, 0.0, 0.0,  
 7 13.0, 12.0, 10.0, 7.0, 5.0, 4.0, 2.0, 0.3, 0.0, 0.0,  
 8 19.0, 13.0, 7.0, 3.0, 2.0, 1.0, 0.3, 0.0, 0.0, 0.0/

T1HE, T2HE, points in time representative of the occurrence of hereditary effects  
 in the first generation following the living generations, and in all  
 following generations, respectively (yr).

DATA T1HE /15./  
 DATA T2HE /50./

### 3.8.2 Cost Calculations

#### Calculation of time-integrated values including discounting:

##### - Cancers

Discount factors, for periods N = 1 to 10

$$DFLH1_N = QLH^{-((IOBS_{N-1} + IOBS_N)/2)+1}$$

with

$$QLH = 1 + (DISHE/100)$$

where

DFLH1<sub>N</sub> = discount factor for periods IOBS<sub>N</sub> (-),

IOBS<sub>N</sub> = periods of time (yr),

DISHE = discount rate (%/yr),

Time-integrated values that describe the "effective" duration of losses to the econ-  
 omy, for MOR = 1 to 2, for cancer types NOG = 1 to 8, for periods N = 1 to 10

$$DFLH2_{N,NOG,MOR} = (1 - QLH^{-TPLE}) / (1 - QLH^{-1})$$

with

$$TPLE = TTRCLH_{NOG,MOR} \quad \text{for MOR} = 1,$$

$$TPLE = TTRCLH_{NOG,MOR} + TLILO_{N,NOG} \quad \text{for MOR} = 2.$$

where

DFLH2<sub>N,NOG,MOR</sub> = time-integrated value including discounting (yr), for the  
 duration of medical treatment and of losses to the economy,

$TTRCLH_{NOG,MOR}$  = effective duration of medical treatment (yr),  
 $TLILO_{N,MOR}$  = number of years of life lost (yr),  
 and the other parameters already explained above.

### - Hereditary effects

Discount factors

$$DFLH3_1 = QLH^{-T1HE+1}$$

$$DFLH3_2 = QLH^{-T2HE+1}$$

where

$DFLH3_{1/2}$  = discount factor for periods T1HE and T2HE (-),

T1HE, T2HE = points in time representative of the occurrence of hereditary effects,

and the other parameters already explained above.

Time-integrated values that describe the "effective" duration of losses to the economy

$$DFLH4 = (1 - QLH^{-TTLHLH}) / (1 - QLH^{-1})$$

where

$DFLH4$  = time-integrated value including discounting (yr), for the duration of medical treatment and of losses to the economy,

$TTLHLH$  = effective duration of medical treatment and number of years of life lost (yr),

and the other parameters already explained above.

### Cost calculations

#### - Cancers

Options 1 and 3

For MOR = 1 to 2, for cancer types NOG = 1 to 8, for periods N = 1 to 10

$$CLHE_{N,NOG,MOR} = GESOG_{N,NOG,MOR} \cdot ULHSC_{NOG,MOR} \cdot DFLH1_N$$

Options 2 and 4

For MOR = 1 to 2, for cancer types NOG = 1 to 8, for periods N = 1 to 10

$$CLHTR = GESOG_{N,NOG,MOR} \cdot ULHTC_{NOG,MOR} \cdot DFLH1_N$$

$$CLHLL = GESOG_{N,NOG,MOR} \cdot UCLOE \cdot DFLH1_N \cdot DFLH2_{N,NOG,MOR}$$

$$CLHE_{N,NOG,MOR} = CLHTR + CLHLL$$

For MOR = 1 to 2

$$CLHTRE_{MOR} = \sum_{N=1}^{10} \sum_{NOG=1}^8 CLHTR$$

$$CLHLOS_{MOR} = \sum_{N=1}^{10} \sum_{NOG=1}^8 CLHLL$$



Summing up of cancer costs - all options

"TYPE A" costs (for MOR = 1 to 2, for periods N = 1 to 10)

$$CLHN_{N,MOR} = \sum_{NOG=1}^8 CLHE_{N,NOG,MOR}$$

"TYPE B" costs (for MOR = 1 to 2, for periods N = 1 to 10)

$$CLHNS_{N,MOR} = CLHNS_{N-1,MOR} + CLHN_{N,MOR}$$

"TYPE A" costs (for periods N = 1 to 10)

$$CLHNN_N = \sum_{MOR=1}^2 CLHN_{N,MOR}$$

"TYPE B" costs (for periods N = 1 to 10)

$$CLHNS_N = CLHNS_{N-1} + CLHNN_N$$

For MOR = 1 to 2, for cancer types NOG = 1 to 8

$$CLHNOG_{NOG,MOR} = \sum_{N=1}^{10} CLHE_{N,NOG,MOR}$$

Total treatment costs (morbidity + mortality == > MOR = 3)

$$CLHTRE_3 = \sum_{MOR=1}^2 CLHTRE_{MOR}$$

Total losses-to-economy costs (morbidity + mortality == > MOR = 3)

$$CLHLOS_3 = \sum_{MOR=1}^2 CLHLOS_{MOR}$$

where

- CLHE<sub>N,NOG,MOR</sub> = health effect costs for MOR = 1 to 2, for each cancer type NOG, for each period N (M.U.),
- CLHTR = medical treatment costs for MOR = 1 to 2, for each cancer type NOG, for each period N (M.U.),
- CLHLL = losses-to-economy costs for MOR = 1 to 2, for each cancer type NOG, for each period N (M.U.),
- CLHTRE<sub>MOR</sub> = total medical treatment costs for MOR = 1 to 3 (M.U.),
- CLHLOS<sub>MOR</sub> = total losses-to-economy costs for MOR = 1 to 3 (M.U.),
- CLHN<sub>N,MOR</sub> = health effect costs "TYPE A", for MOR = 1 to 2, for each period N (M.U.),
- CLHNS<sub>N,MOR</sub> = health effect costs "TYPE B", for MOR = 1 to 2, for each period N (M.U.),
- CLHNN<sub>N</sub> = health effect costs "TYPE A", for each period N (M.U.),
- CLHNS<sub>N</sub> = health effect costs "TYPE B", for each period N (M.U.),
- CLHNOG<sub>NOG,MOR</sub> = health effect costs for MOR = 1 to 2, for each cancer type NOG (M.U.),
- ULHSC<sub>NOG,MOR</sub> = unit costs (total) for MOR = 1 to 2, for each cancer type NOG (M.U./case),

$ULHTC_{NOG,MOR}$  = unit costs (medical treatment) for MOR = 1 to 2,  
 for each cancer type NOG (M.U./case),  
 $UCLOE$  = unit costs of losses to the economy (M.U./case-yr),  
 and the other parameters already explained above.

### - Hereditary Effects

Option 3:

$$\begin{aligned}
 CLHHE &= HER_{L,NS} \cdot ULHSH \cdot DFLH3_1 \\
 &+ (FGESOG_{12} - HER_{L,NS}) \cdot ULHSH \cdot DFLH3_2
 \end{aligned}$$

Option 4:

$$\begin{aligned}
 CLHHE &= HER_{L,NS} \cdot (ULHTH + UCLOE \cdot DFLH4) \cdot DFLH3_1 \\
 &+ (FGESOG_{12} - HER_{L,NS}) \cdot (ULHTH + UCLOE \cdot DFLH4) \cdot DFLH3_2
 \end{aligned}$$

where

$CLHHE$  = total costs, (M.U.),  
 $ULHSH$  = unit costs (total) (M.U./case),  
 $ULHTH$  = unit costs (medical treatment), (M.U./case),  
 and the other parameters already explained above.

For the transfer to the TOTCOS submodule:

$$\begin{aligned}
 CLHTOT_{L,NS} &= \sum_{MOR=1}^2 CLHNS_{10,MOR} + CLHHE \\
 &= \text{total late health effect costs (M.U.)}.
 \end{aligned}$$

### 3.9 TOTCOS Submodule

The TOTCOS submodule is called automatically in each subsystem NE, NL, FL in order to calculate the total costs of all main categories treated in one run.

The total calculated costs CTOT (M.U.) are the sum of one or more of the following costs:

$CSHTOT_{L,NS}$  = total sheltering costs,  
 $CEVTOT_{L,NS}$  = total evacuation costs,  
 $CRLTOT_{L,NS}$  = total relocation costs,  
 $CDCTOT_{L,NS}$  = total decontamination costs,  
 $CFBTOT_{L,NS}$  = total food ban costs,  
 $CEHTOT_{L,NS}$  = total early health effect costs,  
 $CLHTOT_{L,NS}$  = total late health effect costs.

Besides, the fraction of each single main cost category in the total calculated costs is determined in TOTCOS.

### **3.10 EVAECO Module**

The EVAECO module can be called by the main program of COSYMA in each subsystem NE, NL, FL by a steering parameter called *IEVECO*. In this module, the results calculated in ECONOM and stored in a special data file on NUNITS(55) (for details, see Chapter 5.) may be further processed for numerical or graphical presentation.

A probability  $PWET_L \cdot PSTO_{NS}$  is attributed to each case (L,NS), and for each cost category stored on NUNITS(55) the maximum number, the mean number, and percentile values are determined from the total number of cases  $LMAX \cdot NSTMAX$ , as well as the complementary cumulative frequency distribution (CCFD). Furthermore, EVAECO may be used to process the results for plotting.

As already mentioned, standard procedures are used in EVAECO that are applied throughout the whole COSYMA system; they will not be described here in detail. For more information, the reader is referred to /3/.

## 4. Description of User Input

In this chapter, a detailed description will be given of all user input parameters that are necessary for the cost calculations in the ECONOMICS module. Most of these input parameters are attributed to a specific input group called "ECONOMIC" (with the name-list called "ECOPAR"). These are described in detail in Section 4.2. Some other parameters are used either as steering parameters in the ECONOMICS module or also in other COSYMA modules and, therefore, they belong to other input groups. These parameters are described in detail in Section 4.1.

With the exception of a few parameters for which the input is obligatory, so-called **default values (DV)** are provided for all other input parameters. This means that recommended parameter values are incorporated in the code, and the user is free to change them according to his own preferences.

### 4.1 Input Data from Other Input Groups

All parameters from other input groups that are used in the ECONOMICS module are listed in Table 1 and will be explained below:

**LMAX** (input obligatory): number of weather sequences (max. LWMAX = 144).

**NSTMAX** (input obligatory): number of sites (max. NSITMX = 5).

**PWET(L)** (input obligatory): probability of the weather sequence L.

**PSTO(NS)** (input obligatory): probability of the site NS.

**STONAM(NS)** (input obligatory): name of the site NS.

**UNFNAM** (input obligatory): name of the source term.

**NOECON** (DV = 0): steering parameter to call the ECONOM module,

= 0 no call of the ECONOM module,

= 1 call of the ECONOM module.

**IEVECO** (DV = 0): steering parameter to call the EVAECO module,

= 0 no call of the EVAECO module,

= 1 call of the EVAECO module.

**Table 1: Input Data from Other Input Groups**

	N E		N L		F L	
	ECONOM	EVAECO	ECONOM	EVAECO	ECONOM	EVAECO
Input group METEOZON						
LMAX	#	#	#	#	#	#
NSTMAX	#	#	#	#	#	#
PWET(L)		#		#		#
PSTO(NS)		#		#		#
STONAM(NS)	#		#		#	
Input group SOURCE						
UNFNAM		#		#		#
Input group RESULTS						
NOECON	#		#		#	
IEVECO		#		#		#
IDSART	#		#		#	
Input group PRINTOUT						
NOOCOS	#		#		#	
LKZ(L)	#		#		#	
ICCFD		#		#		#
Input group POLGRID						
IMAX	#		#		#	
JMAX	#		#		#	
Input group PROTECT						
DFMAX(N)			#		#	
IEVA1	#					
IEVA2	#					
IMAXSH			#			
ITSH			#			
ITBACK	#					
NNT			#	#	#	#
NOEXPO			#		#	
NT(N)			#		#	
Input group DOSRISK						
IMOR	#	#				
ORBID(NOG)			#		#	
Input group EVALUATE						
NCTMIN		#		#		#
PERC		#		#		#

**IDSART** (DV = 0): option for consideration of countermeasures,  
= 0 no measures,  
≠ 0 measures are taken into account.

**NOOCOS** (DV = 0): flag that controls printout of results in ECONOM,  
= 0 no printout,  
= 1 printout of total costs of each cost category,  
= 2/3 more detailed printout (for details, see Chapter 5.).

**LKZ(L1)** (DV = 1, 7, 50, 75, 90, 115, 14 • 0): gives the index of the weather sequences L for which a printout of costs is given in ECONOM (relevant only if NOOCOS > 0).

**ICCFD** (DV = 0): option to specify whether a printout of CCFDs is given in the EVAECO module,  
= 0 no printout,  
= 1 printout.

**IMAX** (NE/NL: DV = 20; FL: DV = 27): number of radial distances (default values are max. values).

**JMAX** (DV = 72): number of angular segments (default value is max. value).  
Note: IMAX and JMAX are only used for options 2 and 3 in case of sheltering (NL), evacuation (NE) and relocation (NL, FL).

**DFMAX(N)** (DV = 3 • 1.0, 9 • 3.0, 3 • 0.0): maximum decontamination factor for different periods of time N (max. 15).  
Note: DFMAX(N) is used in the ECONOMICS module only as a reminder in connection with the control printout of input data in case of decontamination in the ECODAT sub-module.

**IEVA1** (DV = 7): index of the last inner radius of evacuation area A, i.e. radius of the circle.

**IEVA2** (DV = 10): index of the last outer radius of evacuation area A, i.e. radius of the sector.  
Note: IEVA1 and IEVA2 are only used for options 2 and 3 in case of evacuation.

**IMAXSH** (DV = 0): index of the last radius of the "sheltering only" area.

**ITSH** (DV = 1): duration of "sheltering only" (days).

**ITBACK** (DV = 30): duration of evacuation (days).

**NNT** (DV = 12): number of periods of time considered for relocation and decontamination (max. 15).

**NOEXPO(4)** (DV = 1): specifies whether areas with food bans are to be calculated,

= 0 no calculation,

= 1 calculation.

**NT(N)** (DV = 30, 90, 180, 365, 730, 1825, 3650, 7300, 10950, 14600, 18250, 25550, 3 • 0): periods of time N considered for relocation and decontamination (days).

**Note:** If the user wants to change the default values of NT(N), he has to observe the following rules for the use in the ECONOMICS module: (1) he may select as many periods < 365 days as he wants; (2) if he selects periods > 365 days, he has to start with a value = 365 days; (3) for values > 365 days it is recommended to select values for full years.

**IMOR** (DV = 1): parameter for selecting the category of early health effects to be considered

= 1 morbidity and mortality,

= 2 only mortality.

Note: IMOR is a member of the "DOSRISK" input group in the subsystem NE only; in the ECONOMICS module, IMOR will also be used in the subsystem NL, in this case, it is an input parameter of the "ECONOMIC" input group (see Section 4.2.1).

**ORBID(NOG)** (DV = 1.0, 1.0, 0.40, 0.75, 0.85, 0.55, 1.0, 0.90, 0.10, 0.60, 1.0E-2, 1.0): correction factor for cancer incidence (ratio of fatal cancers to total cancers) for each cancer type NOG (for details, see /8/).

**NCTMIN** (DV = 6):  $10^{\text{NCTMIN}}$  gives the lower limit of cost values for which probability distributions are calculated in the EVAECO module; the upper limit is given by  $10^{8+\text{NCTMIN}}$ .

**PERC(IPZ)** (DV = 99.9, 99.0, 95.0, 90.0, 50.0): percentile values (%) that will be calculated in the EVAECO module.

## 4.2 Input Parameters of the ECONOMIC Input Group

### 4.2.1 General Parameters

The steering parameters that may be used in the subsystems NE, NL and FL of COSYMA to control the calculation of different main cost categories are as follows:

	NE	NL	FL
ICSHE		#	
ICEVA	#		
ICREL		#	#
ICDEC		#	#
ICFOB		#	#
ICEHE	#	#	
ICLHE		#	#

**ICSHE** (DV = 0): flag that controls the calculation of sheltering costs; possible values: 0 or 1 or 2 or 3. The meaning of the ICSHE value is the same as for loss-of-income costs in case of evacuation or relocation. See Notes at the end of ICREL.

**ICEVA** (DV = 0): flag that controls the calculation of evacuation costs; possible values: 0 = no calculation; if ICEVA > 0, the value consists of 3 digits, where the 1st digit refers to transport costs, the 2nd digit to accommodation costs, the 3rd digit to loss-of-income costs.

Value of transport costs: 1 (= reference option),

values of accommodation costs: 0 or 1 or 2,

values of loss-of-income costs: 1 or 2 or 3.

For accommodation and loss-of-income costs:

0 = no calculation,

1 = calculation with site-specific unit costs,

2 = calculation with region-specific unit costs,

3 = calculation with land-use costs.

See Notes at the end of ICREL.

**ICREL** (DV = 0): flag that controls the calculation of relocation costs; possible values: 0 = no calculation; if ICREL > 0, its value consists of 4 digits, where the 1st digit refers to transport costs, the 2nd digit to accommodation costs, the 3rd digit to loss-of-income costs, the 4th digit to lost capital services. In detail:



- transport costs: 1 or 2, where:
    - 1 = reference option,
    - 2 = simplified calculation;
  - accommodation costs: 0 or 1 or 2,
  - loss-of-income costs: 1 or 2 or 3,
  - lost capital services: 1 or 2,
- where:

- 0 = no calculation,
- 1 = calculation using site-specific unit costs,
- 2 = calculation using region-specific unit costs,
- 3 = calculation using land-use costs.

**Important Notes** with respect to the values of ICSHE, ICEVA and ICREL:

(1) Sheltering costs can be calculated only, if there is no relocation and decontamination, i.e., if  $ICSHE > 0 \implies ICREL$  and  $ICDEC$  must be  $= 0$ .

(2) In the case of  $ICEVA > 0$  or  $ICREL > 0$ , it is checked in the code whether **all** of the three cost categories in case of evacuation or **all** of the four cost categories in case of relocation are treated by setting the respective digits  $> 0$ . The only exception - in both cases - are accommodation costs for which it is allowed to set the respective digit  $= 0$ . The reason for this is that the unit costs of accommodation and loss-of-income may have the same origin, namely GDP. If accommodation is included in total GDP and if the data base does not allow to treat this separately, accommodation costs are included in loss-of-income costs and, therefore, the code allows to skip accommodation costs.

The following Notes refer to the selection of options for the calculation of accommodation costs, loss-of-income costs, and costs of lost capital services, respectively:

(3) Option 1 is considered as reference option and is recommended for use. With the exception of unit costs of transport, all other unit cost parameters are **site**-dependent, i.e. the user may use different values for different sites in one run. The default values contained in the code in each case are average values applicable to the Federal Republic of Germany.

(4) Option 2 is considered as a supplementary option. With the exception of unit costs of transport, all other unit cost parameters are **region**-dependent, i.e. the area around the site may be subdivided into different economic areas or regions with the help of a special data file (see below), and different unit cost values may be attributed to each economic region. This subdivision is, of course, site-dependent; therefore, it is not possible to provide default values that are generally valid. For the default values in the code, a

fictive "subdivision" into one economic region (= whole FRG) has been made, i.e. the values refer to the average of the Federal Republic of Germany.

(5) Whenever option 2 is used, an additional data file has to be provided that assigns - for each nuclear site - each grid element (J,I) of the  $r,\phi$ -grid to an economic region. This data file is read in on NUNITS(7) and has the format ((KRE(J,I),J=1,JMAX),I=1,IMAX). This data file is **not included** in the overall COSYMA program package and has to be provided by the user if option 2 is selected.

(6) For the calculation of loss-of-income costs a further option 3 is available which may be used, if the distribution of the GDP is known on the basis of a so-called "land-use" grid. If option 3 is used, an additional data file has to be provided in which - for each nuclear site - the Gross Domestic Product (GDP) is given for the area of each grid element (J,I) of the  $r,\phi$ -grid. This data file is read in on NUNITS(10) and has the format ((ARLOI(J,I),J=1,JMAX),I=1,IMAX). This data file is **not included** in the overall COSYMA program package and has to be provided by the user if option 3 is selected. Additional unit cost values are not required as an input in this case.

**ICDEC** (DV = 0): flag that controls the calculation of decontamination costs; possible values: 0 or 1 or 2, where:

- 0 = no calculation,
- 1 = calculation with area-based unit costs (average over rural and urban areas),
- 2 = calculation with area- and per capita-based unit costs (area-based costs for rural areas, per capita-based costs for urban areas).

**ICFOB** (DV = 0): flag that controls the calculation of food ban costs; possible values: 0 or 1, where:

- 0 = no calculation,
- 1 = calculation using agricultural production grids.

**ICEHE** (DV = 0): flag that controls the calculation of early health effect costs; possible values: 0 or 1 or 2, where:

- 0 = no calculation,
- 1 = subjective valuation approach,
- 2 = human capital approach.

**ICLHE** (DV = 0): flag that controls the calculation of late health effect costs; possible values: 0 or 1 or 2 or 3 or 4, where:

- 0 = no calculation,
- 1 = subjective valuation approach - cancers,

- 2 = human capital approach - cancers,
- 3 = #1 - cancers + hereditary effects,
- 4 = #2 - cancers + hereditary effects.

**IMOR** (DV = 1): parameter for selecting the categories of early health effects to be calculated; possible values: 1 or 2, where:

- 1 = morbidity and mortality,
- 2 = only mortality.

(see also Note about IMOR in Section 4.1).

**CURR** char\*10 (DV = ' 1 DM '): definition of "monetary unit (M.U.)" - only used as a reminder in the printout of the ECODAT submodule.

#### 4.2.2 Sheltering

The following input parameters are used for the calculation of the sheltering costs:

**FUCEC, NRE, UCLOI1(NS), UCLOI2(NR).**

These parameters are the same as for the calculation of the relocation costs and are described in more detail in Section 4.2.4.

Additional parameters that are used for the calculations are

**IMAXSH and ITSH,**

these parameters are described in Section 4.1.

#### 4.2.3 Evacuation

The following input parameters are used for the calculation of evacuation costs:

**FUCEC, NRE, UCACC2(NR), DEPRAC.**

These parameters are the same as for the calculation of relocation costs and are described in more detail in Section 4.2.4.

**SPREV** (DV = 0.8): fraction of population using private transport means (-).

The default value is based on estimates.

Note: By using the default values of UEVTPR and UEVTPU (see below), SPREV is not relevant to the cost calculations as both values are identical.

**UEVTPR** (DV = 10.): unit costs of private transport (M.U./cap). The default value is based on the average costs of running a car: 0.50 (M.U./km), the average distance

between the evacuation area and the destination area: 50 km, the average number of people per car: 2.5.

**UEVTPU** (DV = 10.): unit costs of public transport (M.U./cap). No detailed estimate has been made to determine the default value; the same value as for private transport is used.

**UEVAC1(NS)** (DV = 5 • 30.): unit costs of accommodation for each nuclear site NS, to be used for option 1 (M.U./cap-day). The default value is based on cost estimates (real expenditures) for accommodation in the destination area (mean value of hotel, mass and private accommodation).

**UCLOI1(NS)** (DV = 5 • 30700.): unit costs of loss-of-income for each nuclear site NS, to be used for option 1 (M.U./cap-yr). The default value is based on the Gross Domestic Product (GDP); for a detailed derivation from national economic statistics, see Appendix 4.3.1.

**UCLOI2(NR)** (DV = 30700, 14 • 0.): unit costs of loss-of-income for each economic region NR, to be used for option 2 (M.U./cap-yr). The default value is based on the same model philosophy and, therefore, identical with UCLOI1 - see above.

**RINTEV** (DV = 7.0): interest rate (%/yr), to be used only for the calculation of accommodation costs according to option 2. The default value represents the actual situation in the Federal Republic of Germany in 1989 (= real interest rate + inflation rate).

An additional parameter used for the calculations is

**ITBACK,**

this parameter is described in Section 4.1.

#### **4.2.4 Relocation**

The following input parameters are used for the calculation of relocation costs:

**FUCEC** (DV = 1.0): factor to adjust unit costs in case of sheltering, evacuation and relocation (-).

**Note:** In the ECODAT submodule all unit cost parameters that refer to sheltering, evacuation or relocation are multiplied by FUCEC. The reason of this multiplication is to offer a simple method to adjust unit cost parameters without changing all default values themselves, e.g. if the user wants to use a different base year for the cost calculations or if he wants to change the monetary unit (e.g. from "DM" into "ECU").

**NRE** (DV = 1): number of economic regions (-), (max. NREMAX = 15), to be used for the calculation of accommodation costs, loss-of-income costs and costs of lost capital services according to option 2 in case of sheltering, evacuation and relocation. The input value of NRE depends on the economic situation of each nuclear site that will be modelled by the user. For the default value, a fictitious "subdivision" into one economic area has been made (see also Note (4) on p. 62).

**SPRRL** (DV = 0.8): fraction of population using private transport means (-). The default value is based on estimates.

Note: By using the default values of URLTPR and URLTPU (see below), SPRRL is not relevant to the cost calculations as both values are identical.

**URLTPR** (DV = 50.): unit costs of private transport (M.U./cap). The default value is based on the average costs of running a car: 0.50 (M.U./km), the average distance between the relocation area and the destination area: 200 km, the average number of people per car: 2.0.

**URLTPU** (DV = 50.): unit costs of public transport (M.U./cap). No detailed estimate has been made to determine the default value; the same value as for private transport is used.

**UCACC1(NS)** (DV = 5 • 2300.): unit costs of accommodation for each nuclear site NS, to be used for option 1 (M.U./cap-yr). The default value is based on the GDP contribution of the economic sector "rent of housing"; for a detailed derivation from national economic statistics, see Appendix 4.3.1.

**UCACC2(NR)** (DV = 47600., 14 • 0.): unit costs of accommodation for each economic region NR, to be used for option 2 (M.U./cap). The default value is based on the market value of houses and dwellings; for a detailed derivation from national economic statistics, see Appendix 4.3.2.

**UCLOI1(NS)** (DV = 5 • 30300.): unit costs of loss-of-income for each nuclear site NS, to be used for option 1 (M.U./cap-yr). The default value is based on Gross Domestic Product (GDP); for a detailed derivation from national economic statistics, see Appendix 4.3.1.

**UCLOI2(NR)** (DV = 30300, 14 • 0.): unit costs of loss-of-income for each economic region NR, to be used for option 2 (M.U./cap-yr). The default value is based on the same model philosophy and, therefore, identical with UCLOI1 - see above.

**UCCAP1(NS,K)** (DV = K = 1: 5 • 17300.,  
K = 2: 5 • 81300.,  
K = 3: 5 • 15000.):

unit costs of lost capital services for each nuclear site NS, to be used for option 1 (M.U./cap) (K = 1: non-residential capital, K = 2: housing and buildings, K = 3: consumer durables). The default values are based on capital investments in the national economy as a whole; for a detailed derivation from national economic statistics, see Appendix 4.3.2.

**UCCAP2(NR,K)** (DV = K=1: 17300., 14 • 0.,  
K=2: 81300., 14 • 0.,  
K=3: 15000., 14 • 0.):

unit costs of lost capital services for each economic region NR, to be used for option 2 (M.U./cap). The default values are based on the same model philosophy and, therefore, identical with UCCAP1 - see above.

**UCLAN1(NS)** (DV = 5 • 20.): unit costs of lost capital services (category: "land") for each nuclear site, to be used for option 1 (M.U./m<sup>2</sup>); for the derivation, see Appendix 4.3.2.

**UCLAN2(NR)** (DV = 20., 14 • 0.): unit costs of lost capital services (category: "land") for each economic region, to be used for option 2 (M.U./m<sup>2</sup>). The default value is based on the same model philosophy and, therefore, identical with UCLAN1 - see above.

**RINTRL** (DV = 7.0): interest rate (%/yr). The default value represents the actual situation in the Federal Republic of Germany in 1989 (= real interest rate + inflation rate).

**DEPRAC** (DV = 2.0): depreciation rate for the calculation of accommodation costs to be used for option 2 (%/yr). The default value is based on estimates.

**DEPRCA(K)** (DV = 16.0, 2.0, 16.0): depreciation rate for the calculation of lost capital services (%/yr) (K = 1: non-residential capital, K = 2: housing and buildings, K = 3: consumer durables). The default values are based on estimates.

**DEPRLA** (DV = 0.0): depreciation rate for the calculation of lost capital services (category: "land") (%/yr). The default value is set = 0, as no depreciation of land is assumed during relocation.

**TREC** (DV = 2.0): "recovery time" (yr). The meaning of this parameter is described in more detail in Section 2.5.1.1. The default value is based on estimates.

**DISRL** (DV = 5.0): discount rate (%/yr). The default value represents the actual situation in the Federal Republic of Germany in 1989 (= real interest rate).

**IRLCOS** (DV = 1): flag that controls the transfer of time-dependent cost values to the EVAECO module:

- 1 = based on the total number of people relocated in each period ( = "TYPE A" costs),
- 2 = time-integrated value of #1 ( = "TYPE B" costs),
- 3 = based on the number of people for which relocation ends in each period ( = "TYPE C" costs).

For more details on "TYPE A", "TYPE B" and "TYPE C" costs, see explanations in Section 2.5.1.3 on p. 12.

#### 4.2.5 Decontamination

The following input parameters are used for the calculation of decontamination costs:

**FUCDC** (DV = 1.0): factor to adjust unit costs in case of decontamination (-). The meaning of FUCDC is similar to that of FUCEC, see Note on FUCEC on p. 65.

**UDECA(N)** (DV = 15 • 7.2): area-based unit costs of decontamination for each period N, to be used for options 1 and 2 (M.U./m<sup>2</sup>). The default value refers to a decontamination factor DFMAX = 3 and is based on decontamination costs compiled in /2/.

**UDECP(N)** (DV = 15 • 0.0): per-capita based unit costs of decontamination for each period N, to be used for option 2 (M.U./cap). No reliable information has been found in the literature, therefore, the default value was set = 0.

**FRUR(NS)** (DV = 5 • 1.0): fraction of rural/total area to be decontaminated in case of option 2 for each nuclear site NS (-). If option 1 is used, FRUR(NS) must be = 5 • 1.0.

**Note:** The code checks whether FRUR(NS) = 5 • 1.0 in case of option 1. If this is not the case, an error message is given in the ECODAT submodule and the run is terminated.

**DISDC** (DV = 5.0): discount rate (%/yr). The default value represents the actual situation in the Federal Republic of Germany in 1989 ( = real interest rate).

**IDCCOS** (DV = 1): flag that controls the transfer of time-dependent cost values to the EVAECO module:

- 1 = based on total area decontaminated in each period ( = "TYPE A" costs),
- 2 = time-integrated value of #1 ( = "TYPE B" costs).

For more details on "TYPE A" and "TYPE B" costs, see explanations in Section 2.5.1.3 on p. 12.

## 4.2.6 Food Bans

**Note:** For the calculation of food ban costs up to MAXEKO = 5 agri-economic products IEC = 1 to MAXEKO may be used. The meaning of the various products IEC depends on the agricultural production grids used as basic information. The default sequence of agri-economic products used in the present version of COSYMA is:

IEC = 1: milk (l/yr), IEC = 2: livestock (heads/yr), IEC = 3: crop area (km<sup>2</sup>).

The following input parameters are used for the calculation of food ban costs:

**FUCFB** (DV = 1.0): factor to adjust unit costs in case of food bans (-). The meaning of FUCFB is similar to that of FUCEC, see Note on FUCEC on p. 65.

**UFBPR(K,IEC)** (DV = IEC = 1: 0.66, 0.36,  
IEC = 2: 2.64, 1.42,  
IEC = 3: 0.33, 0.18, 4 • 0.0):

unit costs of lost food for each product IEC (M.U./kg). (K = 1: first year, K = 2: following years). The default values are based on the Gross Output in the first year and on the Gross Domestic Product (GDP) in the following years; for a detailed derivation from national economic statistics, see Appendix 4.3.3.

**UFBLC(K,IEC)** (DV = IEC = 1: 0.62, 0.90,  
IEC = 2: 2.49, 3.61,  
IEC = 3: 0.31, 0.45, 4 • 0.0):

unit costs of lost agricultural capital for each product IEC (M.U./(kg/yr)). (K = 1: non-residential capital, K = 2: buildings). The default values are based on capital investments in agriculture; for a detailed derivation from national economic statistics, see Appendix 4.3.3.

**UFBLA** (DV = 8.0E + 06): unit costs of lost agricultural capital (category: "land") (M.U./km<sup>2</sup>) - for the derivation of this value, see Appendix 4.3.3.

**UFBDS(IEC)** (DV = 0.06, 4 • 0.0): unit costs of disposal of food for each product IEC (M.U./kg). The default values are taken from the NRPB publication /2/.

Note: Disposal costs are assumed only for product IEC = 1: milk; for the latter two products, NRPB assumes that "disposal would be dealt with at the farm using farm labour and equipment, and that there will, therefore, be no direct disposal costs".

**COFAPR(IEC)** (DV = 2.4, 360., 2.9E + 05, 2 • 0.0): conversion factor for each product IEC to convert the unit quantities of the production grids into kg, and to adjust the



data to the base year 1989 (IEC = 1: kg/l, IEC = 2: kg/head, IEC = 3: kg/km<sup>2</sup>-yr); for a detailed derivation of these values, see Appendix 4.3.3.

**COFALA(IEC)** (DV = 1.7E-06, 2.3E-03, 0.48, 2 • 0.0): conversion factor for each product IEC to convert the unit quantities of the production grids into km<sup>2</sup>, and to adjust the data to the base year 1989 (IEC = 1: km<sup>2</sup>/(l/yr), IEC = 2: km<sup>2</sup>/(head/yr), IEC = 3: - ); for a detailed derivation of these values, see Appendix 4.3.3.

**NTRAG** (DV = 3): recovery time (yr). The meaning of this parameter is the same as that of **TREC** in case of relocation; TREC is described in more detail in Section 2.5.1.1. The default value is based on estimates.

Note: NTRAG is an integer parameter, therefore, only integer values are allowed.

**RINTFB** (DV = 7.0): interest rate (%/yr). The default value represents the actual situation in the Federal Republic of Germany in 1989 ( = real interest rate + inflation rate).

**DEPRFB(K)** (DV = 16.0, 2.0, 0.0): depreciation rate for the calculation of lost agricultural capital (%/yr), (K = 1: non-residential capital, K = 2: housing and buildings, K = 3: land). The default values are based on estimates.

**DISFB** (DV = 5.0): discount rate (%/yr). The default value represents the actual situation in the Federal Republic of Germany in 1989 ( = real interest rate).

**IFBCOS** (DV = 1): flag that controls the transfer of time-dependent cost values to the EVAECO module:

- 1 = based on total amounts banned in each period  
( = "TYPE A" costs),
- 2 = time-integrated value of #1 ( = "TYPE B" costs),
- 3 = based on amounts for which ban ends in each period  
( = "TYPE C" costs).

For more details on "TYPE A", "TYPE B" and "TYPE C" costs, see explanations in Section 2.5.1.3 on p. 12.

#### 4.2.7 Early Health Effects

The following input parameters are used for the calculation of early health effect costs:

**FUCHE** (DV = 1.0): factor to adjust unit costs in case of early and late health effects (-). The meaning of FUCHE is similar to that of FUCEC, see Note on FUCEC on p. 65.

**UEHSV(NOG,MOR)** (DV = 5 • 0., 5 • 0.): unit costs of early health effects for each type NOG and for morbidity (MOR = 1) and mortality (MOR = 2), to be used for option 1 (subjective valuation approach) (M.U./case).

Note: The values of UEHSV(NOG,MOR) reflect the **totality** of economic consequences on the society that result from a health effect. They are based on a "subjective valuation" (as indicated by the name of the option); therefore, no default values are given in the code, and the input is subject to the user according to his own assessment.

**UEHTR(NOG,MOR)** (DV = MOR = 1: 3000., 6300., 2100., 0., 6600.,  
MOR = 2: 11100., 1.68E + 05, 85500., 0., 85500.):

unit costs of medical treatment for each health effect type NOG and for morbidity (MOR = 1) and mortality (MOR = 2), to be used for option 2 (human capital approach) (M.U./case). The default values are taken from the NRPB publication /2/ and converted into DM with an exchange rate of 1 £ ≡ 3 DM.

Note: No default values are presented for the cases MOR = 1/NOG = 4: mental retardation and MOR = 2/NOG = 4: pre-/neonatal death, as the author does not consider it reasonable to convert these health effect types into economic costs.

**UCLOE** (DV = 28700.): unit costs of losses to the economy of a health effect to be used for option 2 (M.U./case-yr). The default value is based on the Net National Product at factor costs of the base year 1989 in the Federal Republic of Germany (which is also called "national income").

**DUREH(NOG,MOR)** (DV = MOR = 1: 0.1, 0.1, 0.1, 0.0, 0.1,  
MOR = 2: 39.0, 39.0, 39.0, 0.0, 39.0):

periods of time for the calculation of losses-to-economy costs for each health effect type NOG and for morbidity (MOR = 1) and mortality (MOR = 2), to be used for option 2; includes medical treatment and, if applicable, premature death (yr). The default values for MOR = 1 are based on estimates, values for MOR = 2 represent the average life expectancy weighted over the population of the Federal Republic of Germany.

**DISHE** (DV = 3.0): discount rate (%/yr). The default value is based on estimates taking into account a long-term economic development.

#### 4.2.8 Late Health Effects

The following input parameters used for the calculation of late health effect costs have already been described in Section 4.2.7 - Early Health Effects:

**FUCHE, UCLOE, DISHE.**

Additional input parameters are:

**ULHSC(NOG,MOR)** (DV = 8 • 0., 8 • 0.): unit costs of late health effects - cancers - for each type NOG and for morbidity (MOR = 1) and mortality (MOR = 2), to be used for option 1 (subjective valuation approach) (M.U./case).

See Note on **UEHSV(NOG,MOR)** in Section 4.2.7.

**ULHTC(NOG,MOR)**

(DV = MOR = 1: 78000., 57000., 9000., 2 • 63000., 9000., 78000., 6000.,  
MOR = 2: 78000., 57000., 9000., 2 • 63000., 9000., 78000., 6000.):

unit costs of medical treatment of late health effects - cancers - for each type NOG and for morbidity (MOR = 1) and mortality (MOR = 2), to be used for option 2 (human capital approach) (M.U./case). The default values are taken from the NRPB publication /2/ and converted into DM with an exchange rate of 1 £ ≡ 3 DM.

**TTRCLH(NOG,MOR)** (DV = 8 • 0.5, 8 • 1.0): periods of time of "effective" medical treatment of late health effects - cancers - for each type NOG and for morbidity (MOR = 1) and mortality (MOR = 2), to be used for option 2 (yr). The default values are based on estimates.

Note: Periods of medical treatment make one contribution to the calculation of losses-to-economy costs, another contribution results from the number of years of life lost caused by premature death. Data of the latter contribution are **not** user input but are included in the code (see Section 3.8.1).

**ULHSH** (DV = 0.): unit costs of late health effects - hereditary effects - to be used for option 3 (subjective valuation approach) (M.U./case).

See Note on **UEHSV(NOG,MOR)** in Section 4.2.7.

**ULHTH** (DV = 5.45E + 05): unit costs of medical treatment of late health effects - hereditary effects - to be used for option 4 (human capital approach) (M.U./case). The default values are taken from the NRPB publication /2/ and converted into DM with an exchange rate of 1 £ ≡ 3 DM.

**TTLHLH** (DV = 40.): periods of time for the calculation of losses-to-economy costs for late health effects - hereditary effects - (yr). The default values are based on estimates.

**ILHCOS** (DV = 1): flag that controls the transfer of time-dependent and of cancer-dependent cost values, resp., to the EVAECO module:

- 1 = time-dependent value for each period ( = "TYPE A" costs),
- 2 = time-integrated value of #1 ( = "TYPE B" costs),
- 3 = breakdown into cancer-specific values.

For more details on "TYPE A" and "TYPE B" costs, see explanations in Section 2.5.1.3 on p. 12.

### 4.3 Appendix: Derivation of Economic Input Data from National Economic Statistics

#### 4.3.1 Input Data Derived from Total Economic Production

The calculation of accommodation costs (relocation - option 1) and loss-of-income costs (sheltering, evacuation, relocation - options 1 and 2) is based on the **Gross Domestic Product (GDP)**. The unit costs have to be derived from data of the respective national economic statistics of the Federal Republic of Germany ("Volkswirtschaftliche Gesamtrechnung" = macroeconomic accounting) /9, 10/.

The principal arrangement of these data in statistics of the Federal Republic of Germany is as follows:

+	(1)	Gross Output
-	(2)	Purchased Goods and Services
-----		
=	(3)	<b>Gross Value Added (GVA)</b> (includes (Production Taxes – Subsidies))
+	(4)	Value Added Taxes, Import Taxes
-----		
=	(5)	<b>Gross Domestic Product (GDP)</b> (at market prices)
-	(6)	Depreciations
-----		
=	(7)	<b>Net Domestic Product (NDP)</b> (at market prices)
-	(8)	(Production Taxes – Subsidies), Value Added Taxes, Import Taxes
-----		
=	(9)	<b>Net Domestic Product</b> (at factor costs)

For the cost calculations, the Gross Domestic Product **at factor costs** is used, it can be derived in the following way:

+	(3)	Gross Value Added
-	((8) – (4))	(Production Taxes – Subsidies)
-----		
=	(10)	<b>Gross Domestic Product</b> (at factor costs)

The GDP contribution by the economic sector "Rent of Houses" has to be subtracted from the total GDP as this is treated separately under accommodation costs. Furthermore, as food ban costs will be treated separately, the respective part of the sector "Agriculture" must also be subtracted from the total GDP in order to avoid double counting.

The derivation of data from national economic statistics is as follows:

(in 10 <sup>9</sup> DM/yr)	Base year 1989	
+ Total National Economy:		
+ Gross Value Added		+ 2,076.3
- (Production Taxes - Subsidies)		- 60.0 *)
-----		
= GDP (at factor costs)		= 2,016.3
- Rent of Houses:		
+ Gross Value Added (unadjusted) **)	+ 150.1	
- (Production Taxes - Subsidies)	- 1.8	
- Adjustment **)	- 7.7	
= GDP (at factor costs)	= 140.6	- 140.6
-----		
=		= 1,875.7
- Agriculture (60 % of total sector - see p. 77)		
+ Gross Value Added (unadjusted) **)	+ 21.4	
- (Production Taxes - Subsidies)	+ 2.7	
- Adjustment **)	- 1.1	
= GDP (at factor costs)	= 23.0	- 23.0
-----		
=		= 1,852.7

\*) Estimated value at the time of preparing the input data.

\*\*) Note: "Unadjusted" Gross Value Added means that payments for bank services (belonging to (2): "Purchased Goods and Services") are not subtracted in national economic statistics for single economic sectors; if the "Adjusted" Gross Value Added of a single sector has to be determined, this must be done using estimated values.

With a population of  $61.1 \cdot 10^6$  cap in the Federal Republic of Germany, the unit cost values are determined as follows:

Accommodation costs:

$$UCACC2 = \frac{140.6 \cdot 10^9 \text{ (DM/yr)}}{61.1 \cdot 10^6 \text{ (cap)}} = 2,300 \text{ (DM/cap-yr)}$$

Loss-of-income costs (evacuation):

$$UCLOI1/2 = \frac{1,875.7 \cdot 10^9 \text{ (DM/yr)}}{61.1 \cdot 10^6 \text{ (cap)}} = 30,700 \text{ (DM/cap-yr)}$$

Loss-of-income costs (relocation):

$$UCLOI1/2 = \frac{1,852.7 \cdot 10^9 \text{ (DM/yr)}}{61.1 \cdot 10^6 \text{ (cap)}} = 30,300 \text{ (DM/cap-yr)}$$

### 4.3.2 Input Data Derived from Total Capital Investments

In national economic statistics of the Federal Republic of Germany data on capital investments are available for the categories "Non-residential" and "Housing/Buildings". The data used for the calculations refer to "reproducible fixed assets at reerection costs, net (i.e. with depreciation)" /9, 10/.

These data form the basis for the calculation of the costs of lost capital services (relocation - options 1 and 2), and for the calculation of accommodation costs (evacuation and relocation - option 2).

Note: The calculation of accommodation costs according to option 2 is not based on GDP data but on the market value of houses and dwellings.

In the same way as with GDP, part of the agricultural sector has to be subtracted from total values in order to avoid double counting in connection with food ban costs.

Derivation of data from national economic statistics (base year: 1989):

(in 10 <sup>9</sup> DM)	Non-residential	Housing/Buildings	Total
+ Total National Economy	1,095.8	5,023.9*)	6,119.7
- Agriculture (60 % of total sector)	40.2	58.4	98.6
-----			
=	1,055.6	4,965.5	6,021.1

\*) This value contains an amount of 2,910 \* 10<sup>9</sup> DM that belongs to the economic sector "Rent of Houses" and is used as a basis for the calculation of accommodation costs according to option 2.

For the capital categories "Land" and "Consumer Durables" only very coarse estimates exist in the German statistics. The latest values that are known to the author refer to 1982:

Consumer Durables: 660 • 10<sup>9</sup> DM

Land: 3,400 • 10<sup>9</sup> DM  
(with an annual increase of 212 • 10<sup>9</sup> DM)

For "Consumer Durables" an annual increase of 5 % has been assumed which leads to a total value in 1989 of ca. 930 • 10<sup>9</sup> DM.

For "Land" the same increase has been assumed also for the following years which leads to a total value in 1989 of ca. 5,000 • 10<sup>9</sup> DM.

With a population of 61.1 • 10<sup>9</sup> cap and an area of 248.7 • 10<sup>9</sup> m<sup>2</sup> in the Federal Republic of Germany, the unit cost values are determined as follows:

Costs of lost capital services, "Non-residential":

$$UCCAP1/2 = \frac{1,055.6 \cdot 10^9 \text{ (DM)}}{61.1 \cdot 10^6 \text{ (cap)}} = 17,300 \text{ (DM/cap)}$$

Costs of lost capital services, "Housing":

$$UCCAP1/2 = \frac{4,965.5 \cdot 10^9 \text{ (DM)}}{61.1 \cdot 10^6 \text{ (cap)}} = 81,300 \text{ (DM/cap)}$$

Costs of lost capital services, "Consumer Durables":

$$UCCAP1/2 = \frac{930.0 \cdot 10^9 \text{ (DM)}}{61.1 \cdot 10^6 \text{ (cap)}} = 15,000 \text{ (DM/cap)}$$

Costs of lost capital services, "Land":

$$UCLAN1/2 = \frac{5,000.0 \cdot 10^9 \text{ (DM)}}{248.7 \cdot 10^9 \text{ (m}^2\text{)}} = 20 \text{ (DM/m}^2\text{)}$$

Accommodation costs - option 2:

$$UCACC2 = \frac{2,910.0 \cdot 10^9 \text{ (DM)}}{61.1 \cdot 10^6 \text{ (cap)}} = 47,600 \text{ (DM/cap)}$$

### 4.3.3 Input Data Derived from the Agricultural Sector

For the calculation of food ban costs, economic input data are needed for single agricultural products. These so-called agri-economic products used in the present version of COSYMA are:

IEC = 1: milk,

IEC = 2: livestock,

IEC = 3: crop area.

These products include all major foodstuffs that are produced for human consumption. Not included are e.g. fruits, wine.

The economic input data for these products have also been derived from national economic statistics, especially those of the agricultural sector /9, 10, 11/. (Note: The agricultural sector in German economic statistics includes also the forestry and fishery subsectors) Unfortunately, not all information necessary is available down to the level of single agricultural products; therefore, in some cases simplified assumptions have to be made. The procedure of deriving the input data (together with the assumptions made) will be

described in more detail below. All data refer to the Federal Republic of Germany in the base year 1989.

**Derivation of the unit costs of lost food  $UFBPR_{K,IEC}$**

(with  $K = 1$ : gross output,  $K = 2$ : GDP-contribution):

Annual agricultural production (gross output):

	(10 <sup>9</sup> kg)	(10 <sup>9</sup> DM)	UFBPR(1, IEC) (DM/kg)
IEC=1: milk	24.75	16.35	0.66
IEC=2: livestock (includes beef, pork, mutton)	7.64	20.17	2.64
IEC=3: crop area (includes grain, potatoes, vegetables)	18.60	6.16	0.33
-----			
Total	-----	42.68	-----

The gross output of the **total** agricultural sector amounts to

$$71.7 \cdot 10^9 \text{ DM,}$$

i.e. the fraction of this sector that is dealt with in calculating food ban costs is

$$\frac{42.68 \cdot 10^9}{71.70 \cdot 10^9} = = > 60 \%$$

Because of the lack of more detailed information, it is assumed that this fraction of 60 % is also valid on the level of GDP, i.e. for the calculation of  $UFBPR_{K,IEC}$  with  $K = 2$ . The GDP-contribution of 60 % of the total agricultural sector that will be attributed to the total of agri-economic products has been determined (see p. 74) as

$$23.0 \cdot 10^9 \text{ DM.}$$

This results in a ratio of

$$\frac{\text{GDP contribution}}{\text{gross output}} = \frac{23.0 \cdot 10^9}{42.68 \cdot 10^9} = = > 54 \%$$

Because of the lack of more detailed information, this ratio of 54 % has been assumed to be constant for all agri-economic products. This leads to unit costs of  $UFBPR_{K,IEC}$  with  $K = 2$ :

	$UFBPR_{2,IEC}$ (DM/kg)
IEC = 1: milk	0.36
IEC = 2: livestock	1.42
IEC = 3: crop area	0.18



### Derivation of the unit costs of lost agricultural capital $UFBLC_{K,IEC}$

(with  $K = 1$ : non-residential capital,  $K = 2$ : buildings):

Because of the lack of more detailed information, the following assumptions have been made:

- (1) in the same way as with the gross output and GDP-contribution, 60 % of the total capital investment of the agricultural sector is attributed to the agri-economic products,
- (2) the capital investment that is needed for the production of DM 1 is the same for all agri-economic products.

The first assumption leads to total capital investments for all agri-economic products of

$$\begin{aligned} K = 1: \text{ non-residential capital: } & 40.2 \cdot 10^9 \text{ DM} \\ K = 2: \text{ buildings: } & 58.4 \cdot 10^9 \text{ DM} \end{aligned}$$

The second assumption together with the data on agricultural production (in DM and in kg - see p. 77) leads to the following unit costs of lost agricultural capital  $UFBLC_{K,IEC}$ :

	Fraction of total production (%)	Capital investments		$UFBLC(K, IEC)$	
		K=1 ( $10^9$ DM)	K=2	K=1 (DM/kg)	K=2
IEC=1: milk	38.3	15.4	22.4	0.62	0.90
IEC=2: livestock	47.3	19.0	27.6	2.49	3.61
IEC=3: crop area	14.4	5.8	8.4	0.31	0.45

### Derivation of the unit costs of lost agricultural capital $UFBLA$

For the value of agricultural land only very coarse estimates exist in German statistics. The latest value that is known to the author refers to 1982:

$$720.4 \cdot 10^9 \text{ DM.}$$

In 1982, agricultural land covered a surface on the order of 120,000 km<sup>2</sup>, this leads to a specific land value of  $6 \cdot 10^6$  DM/km<sup>2</sup>. An increase in value of 4 % per year leads to

$$UFBLA = 8 \cdot 10^6 \text{ DM/km}^2 \text{ in 1989.}$$

### Derivation of the $COFAPR_{IEC}$ and $COFALA_{IEC}$ conversion factors

The function of the  $COFAPR_{IEC}$  and  $COFALA_{IEC}$  conversion factors is twofold:

- (1) transfer factor of the unit quantities of the agricultural production grids into the unit quantities of costs (i.e. kg for  $COFAPR$  and km<sup>2</sup> for  $COFALA$ , resp.),

(2) factor to adjust the amounts of the agri-economic products given by the agricultural production grids to the actual situation of the Federal Republic of Germany in 1989.

Note: The agricultural production grids presently used in COSYMA refer to an earlier state than the base year 1989; therefore, the total production of agri-economic products in the grids that relate to the area of the Federal Republic of Germany has been determined in order to compare it with the actual situation in 1989 (see figures on p. 77). The data given by the grids are as follows:

- milk:  $10.4 \cdot 10^9$  (l/yr),
- livestock:  $21.1 \cdot 10^6$  (heads/yr),
- crop area: 64,700 (km<sup>2</sup>).

Additional information needed in the calculation of the conversion factors has been derived from the German national agricultural statistics as follows:

Areas used for the production of agri-economic products:

- milk: 18,000 km<sup>2</sup>,
- livestock: 48,000 km<sup>2</sup>,
- crop area: 31,000 km<sup>2</sup>,

Production of livestock:  $29.2 \cdot 10^6$  (head/yr).

This leads to the following values of the conversion factors:

#### **COFAPR**

Milk:

transfer from l/yr into kg/yr: 1.0 (kg/l),

adjustment from grid to actual FRG situation:

$$\frac{24.75 \cdot 10^9 \text{ (kg/yr)}}{10.4 \cdot 10^9 \text{ (l/yr)} \cdot 1.0 \text{ (kg/l)}} = 2.4$$

$$==> \text{COFAPR}_1 = 1.0 \cdot 2.4 = 2.4 \text{ (kg/l)}$$

Livestock:

transfer from heads/yr into kg/yr:

$$\frac{7.64 \cdot 10^9 \text{ (kg/yr)}}{29.2 \cdot 10^6 \text{ (head/yr)}} = 262 \text{ (kg/head)}$$

adjustment from grid to actual FRG situation:

$$\frac{29.2 \cdot 10^6 \text{ (head/yr)}}{21.1 \cdot 10^6 \text{ (head/yr)}} = 1.38$$

$$==> \text{COFAPR}_2 = 262 \cdot 1.38 = 360 \text{ (kg/head)}$$

Crop area:

transfer from km<sup>2</sup> into kg/yr:

$$\frac{18.6 \cdot 10^9 \text{ (kg/yr)}}{31,000 \text{ (km}^2\text{)}} = 6.0 \cdot 10^5 \text{ (kg/km}^2\text{-yr)}$$

adjustment from grid to actual FRG situation:

$$\frac{31,000 \text{ km}^2}{64,700 \text{ km}^2} = 0.48$$

$$==> \text{COFAPR}_3 = (6.0 \cdot 10^5) \cdot 0.48 = 2.9 \cdot 10^5 \text{ (kg/km}^2\text{-yr)}$$

## COFALA

Milk:

transfer from l/yr into km<sup>2</sup>:

$$\frac{18,000 \text{ km}^2}{24.75 \cdot 10^9 \text{ (l/yr)}} = 0.73 \cdot 10^{-6} \text{ (km}^2\text{/(l/yr))}$$

adjustment from grid to actual FRG situation: = 2.4 (see above)

$$==> \text{COFALA}_1 = (0.73 \cdot 10^{-6}) \cdot 2.4 = 1.7 \cdot 10^{-6} \text{ (km}^2\text{/(l/yr))}$$

Livestock:

transfer from heads/yr into km<sup>2</sup>:

$$\frac{48,000 \text{ km}^2}{29.2 \cdot 10^6 \text{ (head/yr)}} = 1.64 \cdot 10^{-3} \text{ (km}^2\text{/(head/yr))}$$

adjustment from grid to actual FRG situation: 1.38 (see above)

$$==> \text{COFALA}_2 = (1.64 \cdot 10^{-3}) \cdot 1.38 = 2.3 \cdot 10^{-3} \text{ (km}^2\text{/(head/yr))}$$

Crop area:

transfer from km<sup>2</sup> into km<sup>2</sup>: 1.0 (-)

adjustment from grid to actual FRG situation: 0.48 (see above)

$$==> \text{COFALA}_3 = 1.0 \cdot 0.48 = 0.48 \text{ (-)}$$

## 5. Description of the Output

In this chapter, a description of the cost results calculated in the ECONOMICS module is presented. It should be noted here that the default value of the NOOCOS steering parameter is = 0, i.e. no output of the results of the cost calculations is produced in the ECONOM module in this case. On the other hand, if the user sets NOOCOS > 0, he will receive a paper printout of most of the calculated cost results in the ECONOM module for all nuclear sites NS and for those weather sequences L that are indicated in the parameter LKZ<sub>L1</sub>. Besides this, for all important cost categories calculated in the ECONOM module, the results for the set of all nuclear sites NS and all weather sequences L are written on a data file on NUNITS(55) for the transfer to the EVAECO module.

In the EVAECO evaluation program, the maximum number, the mean number and the fractile or percentile values (determined by the input parameter PERC<sub>IPZ</sub>) are calculated for each of the cost categories transferred (for the set of all nuclear sites and all weather sequences). In addition, for all cost results marked with an (\*) in the following text, the complementary cumulative frequency distribution (CCFD) is determined in EVAECO if the respective steering parameter, called ICCFD, is set = 1.

Note: The parameter names used in this chapter are identical with those used in Chapter 3. and in the FORTRAN source program.

### 5.1 Output of the *ECONOM* Module

#### 5.1.1 Sheltering Costs

Paper printout (if NOOCOS > 0):

CSHEL = total sheltering costs.

Transfer to the EVAECO evaluation program:

(\*) CSHEL = total sheltering costs.

#### 5.1.2 Evacuation Costs

Paper printout (if NOOCOS > 0):

CEVTRA = transport costs,  
CEVACC = accommodation costs,  
CEVLOI = loss-of-income costs,  
CEVTOT<sub>L,NS</sub> = total evacuation costs.

Transfer to the EVAECO evaluation program:

- (\*) CEVTRA = transport costs,
- (\*) CEVACC = accommodation costs,
- (\*) CEVLOI = loss-of-income costs,
- (\*) CEVTOT<sub>L,NS</sub> = total evacuation costs.

### 5.1.3 Relocation Costs

Paper printout:

If NOOCOS  $\geq$  1:

- CRLTRS<sub>NNT</sub> = total transport cost,
- CRLACS<sub>NNT</sub> = total accommodation costs,
- CRL LIS<sub>NNT</sub> = total loss-of-income costs,
- CRL LCS<sub>NNT</sub> = total costs of lost capital services,
- CRLTOS<sub>NNT</sub> = total relocation costs,

where

NNT = index of the last period N.

If NOOCOS  $\geq$  2:

Time-dependency of total relocation costs, i.e. costs in each period N,  
with N = 1 to NNT:

- CRLTO<sub>N</sub> = relocation costs "TYPE A",
- CRLTOS<sub>N</sub> = relocation costs "TYPE B",
- CRLTOZ<sub>N</sub> = relocation costs "TYPE C".

If NOOCOS = 3:

Time-dependency of transport costs, accommodation costs, loss-of-income costs and costs of lost capital services in the same sequence as for total relocation costs.

Transfer to the EVAECO evaluation program:

- (\*) CRLTRS<sub>NNT</sub> = total transport costs,
- (\*) CRLACS<sub>NNT</sub> = total accommodation costs,
- (\*) CRL LIS<sub>NNT</sub> = total loss-of-income costs,
- (\*) CRL LCS<sub>NNT</sub> = total costs of lost capital services,
- (\*) CRLTOS<sub>NNT</sub> = total relocation costs.

and time-dependency of total relocation costs, i.e. costs in each period N,  
with N = 1 to NNT:

if IRLCOS = 1:

- CRLTO<sub>N</sub> = relocation costs "Type A",

if IRLCOS = 2:

$CRLTOS_N$  = relocation costs "Type B",

if IRLCOS = 3:

$CRLTOZ_N$  = relocation costs "Type C".

#### 5.1.4 Decontamination Costs

Paper printout:

If NOOCOS  $\geq$  1:

$CDECS_{NNT}$  = total decontamination costs,

where

NNT = index of the last period N.

If NOOCOS  $\geq$  2:

Time-dependency of decontamination costs, i.e. costs in each period N,  
with N = 1 to NNT:

$CDEC_N$  = decontamination costs "Type A",

$CDECS_N$  = decontamination costs "Type B".

Transfer to the EVAECO evaluation program:

(\*)  $CDECS_{NNT}$  = total decontamination costs,

and time-dependency of decontamination costs, i.e. costs in each period N,

with N = 1 to NNT:

if IDCCOS = 1:

$CDEC_N$  = decontamination costs "Type A",

if IDCCOS = 2:

$CDECS_N$  = decontamination costs "Type B".

#### 5.1.5 Food Ban Costs

Paper printout:

If NOOCOS  $\geq$  1:

CFBTPR = total costs of lost food,

CFBTLC = total costs of lost agricultural capital,

CFBTDS = total costs of food disposal,

CFBTOS<sub>MBAN</sub> = total food ban costs,

CFBICS<sub>IEC,MBAN</sub> = total costs for each product type IEC,

where

MBAN = index of the last period N.

If NOOCOS  $\geq$  2:

Time-dependency of total food ban costs, i.e. costs in each period N,  
with N = 1 to MBAN:

CFBTO<sub>N</sub> = food ban costs "Type A",

CFBTOS<sub>N</sub> = food ban costs "Type B",

CFBTOZ<sub>N</sub> = food ban costs "Type C".

If NOOCOS = 3:

Time-dependency of each product IEC in the same sequence as for  
total food ban costs.

Transfer to the EVAECO evaluation program:

(\*) CFBTPR = total costs of lost food,

(\*) CFBTLC = total costs of lost agricultural capital,

(\*) CFBTDS = total costs of food disposal,

(\*) CFBTOS<sub>MBAN</sub> = total food ban costs,

CFBICS<sub>IEC,MBAN</sub> = total costs for each product type IEC,

and time-dependency of total food ban costs, i.e. costs in each period N,  
with N = 1 to MBAN:

if IFBCOS = 1:

CFBTO<sub>N</sub> = food ban costs "Type A",

if IFBCOS = 2:

CFBTOS<sub>N</sub> = food ban costs "Type B",

if IFBCOS = 3:

CFBTOZ<sub>N</sub> = food ban costs "Type C".

### 5.1.6 Early Health Effect Costs

Paper printout:

For MOR = 1 (morbidity) and MOR = 2 (mortality) each:

Option 1:

If NOOCOS  $\geq$  1:

CEHSEV = total costs.

If NOOCOS  $\geq$  2:

CEHE<sub>NOG</sub> = costs of each health effect type NOG ,

Option 2:

If NOOCOS  $\geq$  1:

CEHTRE = total medical treatment costs,

CEHLOS = total losses-to-economy costs,

CEHHUC = total costs.

If NOOCOS  $\geq$  2:

- CEH1<sub>NOG</sub> = medical treatment costs of each health effect type NOG,
- CEH2<sub>NOG</sub> = losses-to-economy costs of each health effect type NOG,
- CEHE<sub>NOG</sub> = total costs of each health effect type NOG.

For the total of "morbidity" and "mortality":

- CEHTOT<sub>L,NS</sub> = total early health effect costs.

Transfer to the EVAECO evaluation program:

For MOR = 1 (morbidity) and MOR = 2 (mortality) each:

Option 1:

- (\*) CEHSEV = total costs,
- and
- (\*) CEHE<sub>NOG</sub> = total costs of each health effect type NOG,

Option 2:

- (\*) CEHTRE = total medical treatment costs,
- (\*) CEHLOS = total losses-to-economy costs,
- (\*) CEHHUC = total costs,
- and
- CEHE<sub>NOG</sub> = total costs of each health effect type NOG.

For the total of "morbidity" and "mortality":

- (\*) CEHTOT<sub>L,NS</sub> = total early health effect costs.

### 5.1.7 Late Health Effect Costs

Paper printout:

Note: For the following, there is: MOR = 1: morbidity, MOR = 2: mortality,  
MOR = 3: morbidity + mortality.

If NOOCOS  $\geq$  1:

For all options:

- CLHNS<sub>10,MOR</sub> = total cancer costs (= costs in period N = 10) for MOR = 1 to 2,
- CLHTOT<sub>L,NS</sub> = total late health effect costs.

In addition for options 2 and 4:

- CLHTRE<sub>MOR</sub> = total medical treatment costs, cancers, for MOR = 1 to 3,
- CLHLOS<sub>MOR</sub> = total losses-to-economy costs, cancers, for MOR = 1 to 3,

In addition for options 3 and 4:

- CLHHE = total costs of hereditary effects,



If NOOCOS  $\geq$  2:

Time-dependency of cancer costs, i.e. costs in each period N, N = 1 to 10:

CLHN<sub>N,MOR</sub> = cancer costs "Type A" for MOR = 1 to 2,

CLHNS<sub>N,MOR</sub> = cancer costs "Type B" for MOR = 1 to 2,

CLHNN<sub>N</sub> = cancer costs "Type A",

CLHNNS<sub>N</sub> = cancer costs "Type B".

Type-dependent cancer costs, i.e. costs for each cancer type NOG:

CLHNOG<sub>NOG,MOR</sub> = costs for each type NOG and for MOR = 1 to 2.

Transfer to the EVAECO evaluation program:

CLHTRE<sub>MOR</sub> = total medical treatment costs, cancers, for MOR = 1 to 3,

CLHLOS<sub>MOR</sub> = total losses-to-economy costs, cancers, for MOR = 1 to 3,

(\*) CLHNS<sub>10,MOR</sub> = total cancer costs (= costs in period N=10) for MOR = 1 to 2,

(\*) CLHHE = total costs of hereditary effects,

(\*) CLHTOT<sub>L,NS</sub> = total late health effect costs,

and

if ILHCOS = 1:

CLHNN<sub>N</sub> = "cancer costs Type A" in each period N,

if ILHCOS = 2:

CLHNNS<sub>N</sub> = "cancer costs Type B" in each period N,

if ILHCOS = 3:

CLHNOG<sub>NOG,MOR</sub> = costs for each cancer type NOG and for MOR = 1 to 2.

### 5.1.8 Total Costs

Paper printout (if NOOCOS > 0):

Each of the following main cost categories that are treated in the run:

CSHTOT<sub>L,NS</sub> = total sheltering costs,

CEVTOT<sub>L,NS</sub> = total evacuation costs,

CRLTOT<sub>L,NS</sub> = total relocation costs,

CDCTOT<sub>L,NS</sub> = total decontamination costs,

CFBTOT<sub>L,NS</sub> = total food ban costs,

CEHTOT<sub>L,NS</sub> = total early health effect costs,

CLHTOT<sub>L,NS</sub> = total late health effect costs,

and in addition:

CTOT = total calculated costs.

Besides this, the fraction of each single main cost category to the total calculated costs is given in the printout.

Transfer to the EVAECO evaluation program:

(\*) CTOT = total calculated costs.

## 5.2 Example of an Output

On the following pages, 89 to 103, an example will be given of the output of the subsystem NL of the ECONOMICS module. The figures in this example are arbitrary and do not represent any specific accident behaviour. The output of the subsystem FL is identical to that of the subsystem NL, with the only exception that early health effect costs are not treated in the subsystem FL. The output of evacuation costs in the subsystem NE is similar to that of relocation costs, but without splitting up by periods of time; and sheltering costs are not presented separately here, because they concern only one cost category.

In each COSYMA run in which the ECONOMICS module is called either separately or in a sequence together with other modules, a general control output of relevant input parameters is presented. Among these parameters, the following ones may be of interest with respect to the calculations in the ECONOMICS module:

- name of the source term,
- number of nuclear sites,
- number of weather sequences,
- additional information about the site(s) and the polar grid,
- probability of the site(s) and the weather sequence(s),
- time-frame to be used for relocation / decontamination,
- time-frame to be used for ingestion / food bans,
- the NOECON, IEVECO, NOOCOS steering parameters.

The complete output of all input parameters of the "ECONOMIC" input group used in the computer run (from the ECODAT submodule) will be shown on pp. 89 to 94. All figures are default values. The output starts with a list of all steering parameters of the main cost categories indicating whether or not a main cost category is treated in this run, this is followed by the input data used for each category.

Note: The figures of the unit costs presented here have already been multiplied by the respective adjustment (or multiplication) factors FUC..

The correct end of the output of ECODAT is marked with:

```
***** END OF INPUT WITHOUT ERROR *****
```

On pp. 95 to 99, the output of the other submodules of ECONOM will be shown for each of the main cost categories "Relocation", "Decontamination", "Food Bans", "Early Health Effects" and "Late Health Effects". The NOOCOS steering parameter is set = 3 in this

example; this provides the maximum possible output in ECONOM (for more details concerning lower values of NOOCOS, see Section 5.1). One site, i.e. NSTMAX = 1, and within LKZ<sub>L1</sub> one value, i.e. LKZ<sub>1</sub> = 99, have been selected in this example.

On p. 100, the output of the TOTCOS submodule will be shown, which presents an overview of the total costs of all main cost categories treated in this run.

The output of the EVAECO module is not presented here in full detail, because all results are arranged in the same manner. The output of EVAECO again starts with a list of all steering parameters of the main cost categories indicating whether or not a main cost category is treated, this is followed by the information of the range of costs considered for the evaluations (see p. 101).

As an example of the output, the evaluation of "Total Calculated Costs" will be given on p. 102. From the set of the results of all sites and all weather sequences NSTMAX • LMAX it shows

- the maximum number,
- the mean number,
- SUM P < COSTMIN, i.e. the sum of the probabilities of all cases of the NSTMAX • LMAX set for which the cost values are lower than  $10^{\text{NCTMIN}}$  M.U.,
- the fractiles for 99.9, 99.0, 95.0, 90.0 and 50.0 %.

As CCFD is set = 1 in this example, also the "Complementary Cumulative Frequency Distribution" in the range of costs from  $0.1 \cdot 10^7$  to  $0.1 \cdot 10^{16}$  M.U. is shown in the example.

The output of EVAECO ends with a summary of the mean numbers of all main cost categories and the total calculated costs (see p. 103).

```

EEEEEEEEEE   CCCCCCCCC   0000000000   NN       NN   0000000000   MMM       MMM
EEEEEEEEEEEE   CCCCCCCCCCCC   000000000000   NNN      NN   000000000000   MMMM      MMMM
EE           CC           00           00   NNNN     NN   00           00   MM MM     MM MM
EE           CC           00           00   NN NN     NN   00           00   MM MMMM   MM
EE           CC           00           00   NN NN     NN   00           00   MM MMM   MM
EEEEEEEEEE   CC           00           00   NN NN     NN   00           00   MM M     MM
EEEEEEEEEE   CC           00           00   NN NN     NN   00           00   MM           MM
EE           CC           00           00   NN NN     NN   00           00   MM           MM
EE           CC           00           00   NN NN     NN   00           00   MM           MM
EE           CC           00           00   NN NN     NN   00           00   MM           MM
EEEEEEEEEEEE   CCCCCCCCCCCC   000000000000   NN       NN   000000000000   MM           MM
EEEEEEEEEEEE   CCCCCCCCCC   0000000000   NN       NN   0000000000   MM           MM

```

ECONOM CALCULATES THE ECONOMIC COSTS

\*\*\*\*\* PROGRAM SYSTEM C O S Y M A / N L \*\*\*\*\* PROGRAM UNIT E C O N O M \*\*\*\*\* SUBROUTINE E C O D A T \*\*\*\*\*

COST CATEGORIES TO BE CALCULATED (IC... = 0 ==> NO COST CALCULATIONS, IC... > 0 ==> COST CALCULATIONS):

```

SHELTERING COSTS:           ICSHE = 0
RELOCATION COSTS             ICREL = 1111
DECONTAMINATION COSTS:     ICDEC = 1
FOOD BAN COSTS:            ICFOB = 1
EARLY HEALTH EFFECTS COSTS: ICEHE = 2
LATE HEALTH EFFECTS COSTS:  ICLHE = 4

```

INPUT VALUES TO BE USED:  
 (ALL COST VALUES IN "MONETARY UNITS (M.U.)", 1 M.U. = 1 DM )

RELOCATION  
\*\*\*\*\*

FACTOR TO ADJUST UNIT COSTS: FUCEC = 1.0000

TRANSPORT COSTS -----	ACCOMMODATION COSTS -----	LOSS-OF-INCOME COSTS -----	COST OF LOST CAPITAL SERVICES -----
OPTION 1	OPTION 1	OPTION 1	OPTION 1
UNIT COSTS (ADJUSTED):			
PRIVATE/PUBLIC (M.U./CAP)	UCACC1(NS) (M.U./CAP-YR)	UCLO11(NS) (M.U./CAP-YR)	UCCAP1(NS,K) (M.U./CAP)
URLTPR = 50.	(1) = 2300.	(1) = 30300.	(K=1: NON-RESIDENT., K=2: HOUSING,
URLTPU = 50.	(2) = 2300.	(2) = 30300.	K=3: CONSUMER DURABLES)
			(1,1) = 17300.
			(1,2) = 81300.
			(1,3) = 15000.
			(2,1) = 17300.
			(2,2) = 81300.
			(2,3) = 15000.
			UCLAN1(NS) (LAND) (M.U./M**2)
			(1) = 20.00
			(2) = 20.00

GENERAL INPUT VALUES:

SHARE OF PEOPLE USING PRIVATE TRANSPORT MEANS, SPRRL = 0.80 (-)  
 RECOVERY TIME, TREC = 2.00 (YR)  
 INTEREST RATE, RINTRL = 7.00 (%/YR)  
 DISCOUNT RATE, DISRL = 5.00 (%/YR)  
 DEPRECIATION RATE LOST CAPITAL SERVICES, DEPRCA(K) = 16.00 / 2.00 / 16.00 (%/YR), DEPRLA = 0.00 (%/YR)

DECONTAMINATION  
\*\*\*\*\*

FACTOR TO ADJUST UNIT COSTS: FUCDC = 1.0000

OPTION TO BE USED FOR COST CALCULATIONS: OPTION 1 - AREA-BASED CALCULATION

UNIT COSTS (ADJUSTED):

AREA-BASED VALUES, UDECA(N) (M.U./M\*\*2)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
UDECA(N)	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.20
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	
UDECA(N)	7.20	7.20	7.20	7.20				

GENERAL INPUT VALUES:

DISCOUNT RATE, DISDC = 5.00 (%/YR)

AS A REMINDER: DECONTAMINATION FACTOR, DFMAX(N) (-)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
DFMAX(N)	1.0	1.0	1.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0			

FOOD BANS  
\*\*\*\*\*

FACTOR TO ADJUST UNIT COSTS: FUCFB = 1.0000

OPTION TO BE USED FOR COST CALCULATIONS: OPTION 1 - CALCUALTION BASED ON AGRICULTURAL PRODUCTION GRIDS

UNIT COSTS (ADJUSTED):

AGRO-ECON. PRODUCT	UNIT OF PROD. GRID	LOST FOOD	LOST CAPITAL SERV.	DISPOSAL
MILK	( L/A)	UFBPR(K,1) (M.U./KG) (K=1) = 0.66 (K=2) = 0.36	UFBLC(K,1) (M.U./KG/YR) (K=1) = 0.62 (K=2) = 0.90	UFBDS(1) (M.U./KG) = 0.06
LIFESTCK	( HEADS/A)	UFBPR(K,2) (M.U./KG) (K=1) = 2.64 (K=2) = 1.42	UFBLC(K,2) (M.U./KG/YR) (K=1) = 2.49 (K=2) = 3.61	UFBDS(2) (M.U./KG) = 0.00
CROPAREA	( KM**2)	UFBPR(K,3) (M.U./KG) (K=1) = 0.33 (K=2) = 0.18	UFBLC(K,3) (M.U./KG/YR) (K=1) = 0.31 (K=2) = 0.45	UFBDS(3) (M.U./KG) = 0.00

LOST AGRICULTURAL LAND: UFBLA = 8000000. (M.U./KM\*\*2)

GENERAL INPUT VALUES:

RECOVERY TIME, NTRAG = 3 (YR)  
 INTEREST RATE, RINTFB = 7.00 (%/YR)  
 DISCOUNT RATE, DISFB = 5.00 (%/YR)  
 DEPRECIATION RATE LOST CAPITAL SERVICES, DEPRFB(K) = 16.00 / 2.00 / 0.00 (%/YR)

CONVERSION FACTOR, COFAPR(IEC) (KG/\*\*\*\*) COFALA(IEC) (KM\*\*2/\*\*\*\*)  
 (1) = 2.4000 (1) = 0.00000170  
 (2) = 360.0000 (2) = 0.00230000  
 (3) = 290000.000 (3) = 0.48000002

( "\*\*\*\*" REFERS TO THE UNITS OF THE PRODUCTION GRID)

EARLY HEALTH EFFECTS  
\*\*\*\*\*

IMOR = 1: COST CATEGORIES = MORBIDITY AND MORTALITY

FACTOR TO ADJUST UNIT COSTS: FUCHE = 1.0000

OPTION TO BE USED FOR COST CALCULATIONS: OPTION 2 - HUMAN CAPITAL APPROACH

UNIT COSTS (ADJUSTED):

MEDICAL TREATMENT COSTS,  
UEHTR(NOG,MOR) (M.U./CASE)

(1,1) =	3000.	(1,2) =	11100.
(2,1) =	6300.	(2,2) =	168000.
(3,1) =	2100.	(3,2) =	85500.
(4,1) =	0.	(4,2) =	0.
(5,1) =	6600.	(5,2) =	85500.

LOSSES-TO-ECONOMY COSTS,  
UCLOE = 28700. (M.U./CASE-YR)

GENERAL INPUT VALUES:

EFF. DURATION OF LOSSES-TO-ECONOMY,  
DUREH(NOG,MOR) (YR)

(1,1) =	0.10	(1,2) =	39.00
(2,1) =	0.10	(2,2) =	39.00
(3,1) =	0.10	(3,2) =	39.00
(4,1) =	0.00	(4,2) =	0.00
(5,1) =	0.10	(5,2) =	39.00

DISCOUNT RATE, DISHE = 3.00 (%/YR)



LATE HEALTH EFFECTS  
\*\*\*\*\*

FACTOR TO ADJUST UNIT COSTS: FUCHE = 1.0000

OPTION TO BE USED FOR COST CALCULATIONS: OPTION 4 - HUMAN CAPITAL APPROACH

UNIT COSTS (ADJUSTED):

FATAL AND NON-FATAL CANCERS

HEREDITARY EFFECTS

MEDICAL TREATMENT COSTS,  
ULHTC(NOG,MOR) (M.U./CASE)

MEDICAL TREATMENT COSTS,  
ULHTH = 540000. (M.U./CASE)

(1,1) = 78000.	(1,2) = 78000.
(2,1) = 57000.	(2,2) = 57000.
(3,1) = 9000.	(3,2) = 9000.
(4,1) = 63000.	(4,2) = 63000.
(5,1) = 63000.	(5,2) = 63000.
(6,1) = 9000.	(6,2) = 9000.
(7,1) = 78000.	(7,2) = 78000.
(8,1) = 6000.	(8,2) = 6000.

LOSSES-TO-ECONOMY COSTS,  
UCLOE = 28700.(M.U./CASE-YR)

LOSSES-TO-ECONOMY COSTS  
UCLOE = 28700. (M.U./CASE-YR)

GENERAL INPUT VALUES:

EFF. DURATION OF MED. TREATMENT,  
TTRCLH(NOG,MOR) (YR)

EFF. DURATION OF MED. TREATM.  
+ NO. OF YEARS OF LIFE LOST,  
TTLHLH = 40.00 (YR)

(1,1) = 0.50	(1,2) = 1.00
(2,1) = 0.50	(2,2) = 1.00
(3,1) = 0.50	(3,2) = 1.00
(4,1) = 0.50	(4,2) = 1.00
(5,1) = 0.50	(5,2) = 1.00
(6,1) = 0.50	(6,2) = 1.00
(7,1) = 0.50	(7,2) = 1.00
(8,1) = 0.50	(8,2) = 1.00

DISCOUNT RATE, DISHE = 3.00 (%/YR)

\*\*\*\*\* END OF INPUT WITHOUT ERROR \*\*\*\*\*

\*\*\*\*\* PROGRAM SYSTEM C O S Y M A / N L \*\*\*\*\* PROGRAM UNIT E C O N O M \*\*\*\*\* SUBROUTINE R E L C O S \*\*\*\*\*

\*\*\*\*\* CALCULATION OF RELOCATION COSTS \*\*\*\*\*

\*\*\*\*\*

(ALL COST VALUES IN "MONETARY UNITS (M.U.)", 1 M.U. = 1 DM )

NR. OF SITE      NAME OF SITE  
\*\*\*\*\*

1                      AAAAAAA

NR. OF WEATHER SEQUENCE

TOTAL COSTS:	TRANSPORT	ACCOMMODATION	LOSS-OF-INCOME	LOST CAPITAL SERV.	GRAND TOTAL
99	0.4189E+06	0.3266E+08	0.4303E+09	0.4804E+09	0.9438E+09

TIME-DEPENDENCY OF COSTS:

99 TOTAL COSTS:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
- TYPE A	0.2380E+08	0.4631E+08	0.6945E+08	0.1428E+09	0.2644E+09	0.2220E+09	0.1559E+09	0.1310E+08
- TYPE B	0.2380E+08	0.7011E+08	0.1396E+09	0.2823E+09	0.5467E+09	0.7687E+09	0.9246E+09	0.9377E+09
- TYPE C	0.2838E+06	0.1682E+05	0.0000E+00	0.5322E+05	0.8276E+08	0.2614E+09	0.5488E+09	0.2783E+08
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	
	0.3427E+07	0.1656E+07	0.7422E+06	0.2833E+06				
	0.9411E+09	0.9428E+09	0.9435E+09	0.9438E+09				
	0.4043E+07	0.5101E+07	0.7775E+07	0.5715E+07				

99 TRANSPORT COSTS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
- TYPE A	0.3684E+06	0.7800E+02	0.0000E+00	0.0000E+00	0.5039E+05	0.0000E+00	0.0000E+00	0.0000E+00
- TYPE B	0.3684E+06	0.3685E+06	0.3685E+06	0.3685E+06	0.4189E+06	0.4189E+06	0.4189E+06	0.4189E+06
- TYPE C	0.4770E+04	0.1560E+03	0.0000E+00	0.0000E+00	0.1033E+06	0.1230E+06	0.1814E+06	0.5295E+04
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	
	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00				
	0.4189E+06	0.4189E+06	0.4189E+06	0.4189E+06				
	0.2010E+03	0.3840E+03	0.9600E+02	0.2370E+03				

FOR NOOCOS = 3, THE SAME PRESENTATION OF RESULTS IS ALSO GIVEN FOR:

99 ACCOMMODATION COSTS, LOSS-OF-INCOME COSTS, COST OF LOST CAPITAL SERVICES

\*\*\*\*\* PROGRAM SYSTEM C O S Y M A / N L \*\*\*\*\* PROGRAM UNIT E C O N O M \*\*\*\*\* SUBROUTINE D E C C O S \*\*\*\*\*

\*\*\*\*\* CALCULATION OF DECONTAMINATION COSTS \*\*\*\*\*  
 \*\*\*\*\*  
 (ALL COST VALUES IN "MONETARY UNITS (M.U.)", 1 M.U. = 1 DM )

NR. OF SITE NAME OF SITE  
 \*\*\*\*\*

1 AAAAAAA

NR. OF WEATHER SEQUENCE

TOTAL COSTS:  
 99 0.1189E+09

TIME-DEPENDENCY OF COSTS:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
- TYPE A	0.0000E+00	0.0000E+00	0.0000E+00	0.4562E+06	0.3653E+08	0.2614E+08	0.5193E+08	0.2789E+07
- TYPE B	0.0000E+00	0.0000E+00	0.0000E+00	0.4562E+06	0.3699E+08	0.6313E+08	0.1151E+09	0.1178E+09
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	
	0.4306E+06	0.2626E+06	0.3037E+06	0.5844E+05				
	0.1183E+09	0.1185E+09	0.1188E+09	0.1189E+09				

\*\*\*\*\* PROGRAM SYSTEM C O S Y M A / N L \*\*\*\*\* PROGRAM UNIT E C O N O M \*\*\*\*\* SUBROUTINE F O B C O S \*\*\*\*\*

\*\*\*\*\* CALCULATION OF FOOD BAN COSTS \*\*\*\*\*

\*\*\*\*\*

(ALL COST VALUES IN "MONETARY UNITS (M.U.)", 1 M.U. = 1 DM )

NR. OF SITE NAME OF SITE  
\*\*\*\*\*

1 AAAAAAA

NR. OF WEATHER SEQUENCE

99	TOTAL COSTS:	LOST FOOD 0.3253E+08	LOST CAPITAL 0.1896E+09	DISPOSAL 0.2541E+06	GRAND TOTAL 0.2223E+09
		MILK 0.1712E+08	LIFESTCK 0.1805E+09	CROPAREA 0.2475E+08	

TIME-DEPENDENCY OF COSTS:

99	TOTAL COSTS:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
-	TYPE A	0.1148E+07	0.3351E+07	0.9364E+07	0.1374E+08	0.1894E+08	0.2454E+08	0.5796E+08	0.4114E+08	0.4759E+08
-	TYPE B	0.1148E+07	0.4499E+07	0.1386E+08	0.2760E+08	0.4653E+08	0.7107E+08	0.1290E+09	0.1702E+09	0.2178E+09
-	TYPE C	0.3109E+05	0.6107E+05	0.3486E+05	0.8537E+07	0.5208E+07	0.1354E+07	0.4890E+08	0.1497E+08	0.1285E+09
		(10)	(11)	(12)	(13)	(14)	(15)			
-	TYPE A	0.4226E+07	0.3655E+06							
-	TYPE B	0.2220E+09	0.2223E+09							
-	TYPE C	0.9863E+07	0.4891E+07							

MILK

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
-	TYPE A	0.9478E+05	0.2843E+06	0.8036E+06	0.1182E+07	0.2364E+07	0.3051E+07	0.6260E+07	0.1902E+07	0.9763E+06
-	TYPE B	0.9478E+05	0.3791E+06	0.1183E+07	0.2365E+07	0.4728E+07	0.7779E+07	0.1404E+08	0.1594E+08	0.1692E+08
-	TYPE C	0.0000E+00	0.9576E+03	0.0000E+00	0.0000E+00	0.0000E+00	0.6522E+06	0.9781E+07	0.3312E+07	0.2638E+07
		(10)	(11)	(12)	(13)	(14)	(15)			
-	TYPE A	0.1877E+06	0.2043E+05							
-	TYPE B	0.1710E+08	0.1712E+08							
-	TYPE C	0.4188E+06	0.3211E+06							

FOR NOOCOS = 3, THE SAME PRESENTATION OF RESULTS IS ALSO GIVEN FOR:  
LIFESTCK, CROPAREA

\*\*\*\*\* PROGRAM SYSTEM C O S Y M A / N L \*\*\*\*\* PROGRAM UNIT E C O N O M \*\*\*\*\* SUBROUTINE E H E C O S \*\*\*\*\*

\*\*\*\*\* CALCULATION OF EARLY HEALTH EFFECTS COSTS \*\*\*\*\*

\*\*\*\*\*

(ALL COST VALUES IN "MONETARY UNITS (M.U.)", 1 M.U. = 1 DM )

HEALTH EFFECTS CATEGORY: \*\*\*\*\* MORBIDITY \*\*\*\*\*

NR. OF SITE NAME OF SITE  
\*\*\*\*\*

1 AAAAAAA

NR. OF WEATHER SEQUENCE

	TOTAL COSTS:	LUNG FUNCT. IMP.	HYPOTHYROIDISM	CATARACTS	MENT.RETARDAT.	EFFECTS ON SKIN	GRAND TOTAL
99	MED. TREATM.	0.4003E+05	0.9453E+05	0.3594E+04	0.0000E+00	0.0000E+00	0.1382E+06
	LOSS.ECONOMY	0.3830E+05	0.4306E+05	0.4911E+04	0.0000E+00	0.0000E+00	0.8627E+05
	TOTAL	0.7833E+05	0.1376E+06	0.8505E+04	0.0000E+00	0.0000E+00	0.2244E+06

HEALTH EFFECTS CATEGORY: \*\*\*\*\* MORTALITY \*\*\*\*\*

NR. OF SITE NAME OF SITE  
\*\*\*\*\*

1 AAAAAAA

NR. OF WEATHER SEQUENCE

	TOTAL COSTS:	PULMONARY SYNDR.	HEMATOPOIETIC S.	GASTROINTEST. S.	PRE-/NEONATAL D.	SKIN BURNS	GRAND TOTAL
99	MED. TREATM.	0.1101E+06	0.2567E+06	0.0000E+00	0.0000E+00	0.0000E+00	0.3668E+06
	LOSS.ECONOMY	0.6689E+07	0.1030E+07	0.0000E+00	0.0000E+00	0.0000E+00	0.7719E+07
	TOTAL	0.6799E+07	0.1287E+07	0.0000E+00	0.0000E+00	0.0000E+00	0.8086E+07

HEALTH EFFECTS CATEGORY: \*\*\*\*\* MORBIDITY AND MORTALITY \*\*\*\*\*

NR. OF SITE NAME OF SITE  
\*\*\*\*\*

1 AAAAAAA

NR. OF WEATHER SEQUENCE

	TOTAL COSTS MORBIDITY + MORTALITY
99	0.8310E+07

\*\*\*\*\* PROGRAM SYSTEM C O S Y M A / N L \*\*\*\*\* PROGRAM UNIT E C O N O M \*\*\*\*\* SUBROUTINE L H E C O S \*\*\*\*\*

\*\*\*\*\* CALCULATION OF LATE HEALTH EFFECTS COSTS \*\*\*\*\*

\*\*\*\*\*

(ALL COST VALUES IN "MONETARY UNITS (M.U.)", 1 M.U. = 1 DM )

NR. OF SITE NAME OF SITE

\*\*\*\*\*

1 AAAAAAA

NR. OF WEATHER SEQUENCE

TOTAL COSTS:	CANCERS, MORBIDITY	CANCERS, MORTALITY	HERED. EFFECTS	GRAND TOTAL
- MED. TREATMENT	0.7153E+07	0.1784E+08		0.2499E+08
- LOSS. ECONOMY	0.7426E+07	0.6987E+08		0.7730E+08
- HERED. EFFECTS			0.7866E+08	0.7866E+08
99 TOTAL	0.1458E+08	0.8771E+08	0.7866E+08	0.1810E+09

TIME-DEPENDENCY OF COSTS OF CANCERS:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
99 MORBIDITY:										
- TYPE A	0.2678E+06	0.6372E+06	0.1551E+07	0.1918E+07	0.2197E+07	0.2406E+07	0.4025E+07	0.1400E+07	0.1727E+06	0.4775E+04
- TYPE B	0.2678E+06	0.9049E+06	0.2456E+07	0.4374E+07	0.6571E+07	0.8977E+07	0.1300E+08	0.1440E+08	0.1457E+08	0.1458E+08

MORTALITY:

- TYPE A	0.4321E+07	0.1734E+08	0.2480E+08	0.1509E+08	0.9902E+07	0.6523E+07	0.7310E+07	0.2016E+07	0.3987E+06	0.7616E+04
- TYPE B	0.4321E+07	0.2166E+08	0.4646E+08	0.6156E+08	0.7146E+08	0.7798E+08	0.8529E+08	0.8731E+08	0.8771E+08	0.8771E+08

MORBIDITY + MORTALITY:

- TYPE A	0.4589E+07	0.1798E+08	0.2635E+08	0.1701E+08	0.1210E+08	0.8930E+07	0.1134E+08	0.3416E+07	0.5714E+06	0.1239E+05
- TYPE B	0.4589E+07	0.2257E+08	0.4892E+08	0.6593E+08	0.7803E+08	0.8696E+08	0.9829E+08	0.1017E+09	0.1023E+09	0.1023E+09

99 BREAKDOWN OF CANCER COSTS INTO ORGANS:

	MORBIDITY	MORTALITY
BONE MARROW	0.0000E+00	0.4921E+08
BONE SURFACE	0.0000E+00	0.1773E+07
BREAST	0.1342E+07	0.2962E+07
LUNG	0.1351E+07	0.1077E+08
GI - TRACT	0.1375E+07	0.1547E+08
THYROID	0.8428E+07	0.3556E+07
REMAINDER	0.1005E+07	0.3846E+07
SKIN	0.1077E+07	0.1338E+06

\*\*\*\*\* PROGRAM SYSTEM C O S Y M A / N L \*\*\*\*\* PROGRAM UNIT E C O N O M \*\*\*\*\* SUBROUTINE T O T C O S \*\*\*\*\*

\*\*\*\*\* CALCULATION OF TOTAL COSTS \*\*\*\*\*

\*\*\*\*\*

(ALL COST VALUES IN "MONETARY UNITS (M.U.)", 1 M.U. = 1 DM )

NR. OF SITE NAME OF SITE  
 \*\*\*\*\*

1 AAAAAAA

NR. OF WEATHER SEQUENCE

	FRACTION (%)	TOTAL COSTS
RELOCATION COSTS	64.02	0.9438E+09
DECONTAMINATION COSTS	8.06	0.1189E+09
FOOD BAN COSTS	15.08	0.2223E+09
EARLY HEALTH EFFECTS COSTS	0.56	0.8310E+07
LATE HEALTH EFFECTS COSTS	12.27	0.1810E+09
=====	=====	=====
99 TOTAL CALCULATED COSTS	100.00	0.1474E+10

\*\*\*\*\* PROGRAM SYSTEM C O S Y M A / N L \*\*\*\*\* PROGRAM UNIT E V A E C O \*\*\*\*\*

COST CATEGORIES TO BE EVALUATED (IC... = 0 ==> NO COST EVALUATIONS, IC... > 0 ==> COST EVALUATIONS):

SHELTERING COSTS:	ICSHE =	0
RELOCATION COSTS:	ICREL =	1111
DECONTAMINATION COSTS:	ICDEC =	1
FOOD BAN COSTS:	ICFOB =	1
EARLY HEALTH EFFECTS COSTS:	ICEHE =	2
LATE HEALTH EFFECTS COSTS:	ICLHE =	4

ALL COST VALUES IN "MONETARY UNITS (M.U.)", 1 M.U. = 1 DM )

RANGE OF EVALUATIONS:

NCTMIN:	6
NDEKCT:	8

EVALUATION INTERVALS:

LOWER LIMIT OF COST VALUES:	0.1000E+07
UPPER LIMIT OF COST VALUES:	0.1000E+15

A PRINTOUT OF CCFDS IS GIVEN: ICCFD = 1



\*\*\*\* EVALUATION OF TOTAL CALCULATED COSTS \*\*\*\*  
 \*\*\*\*\*

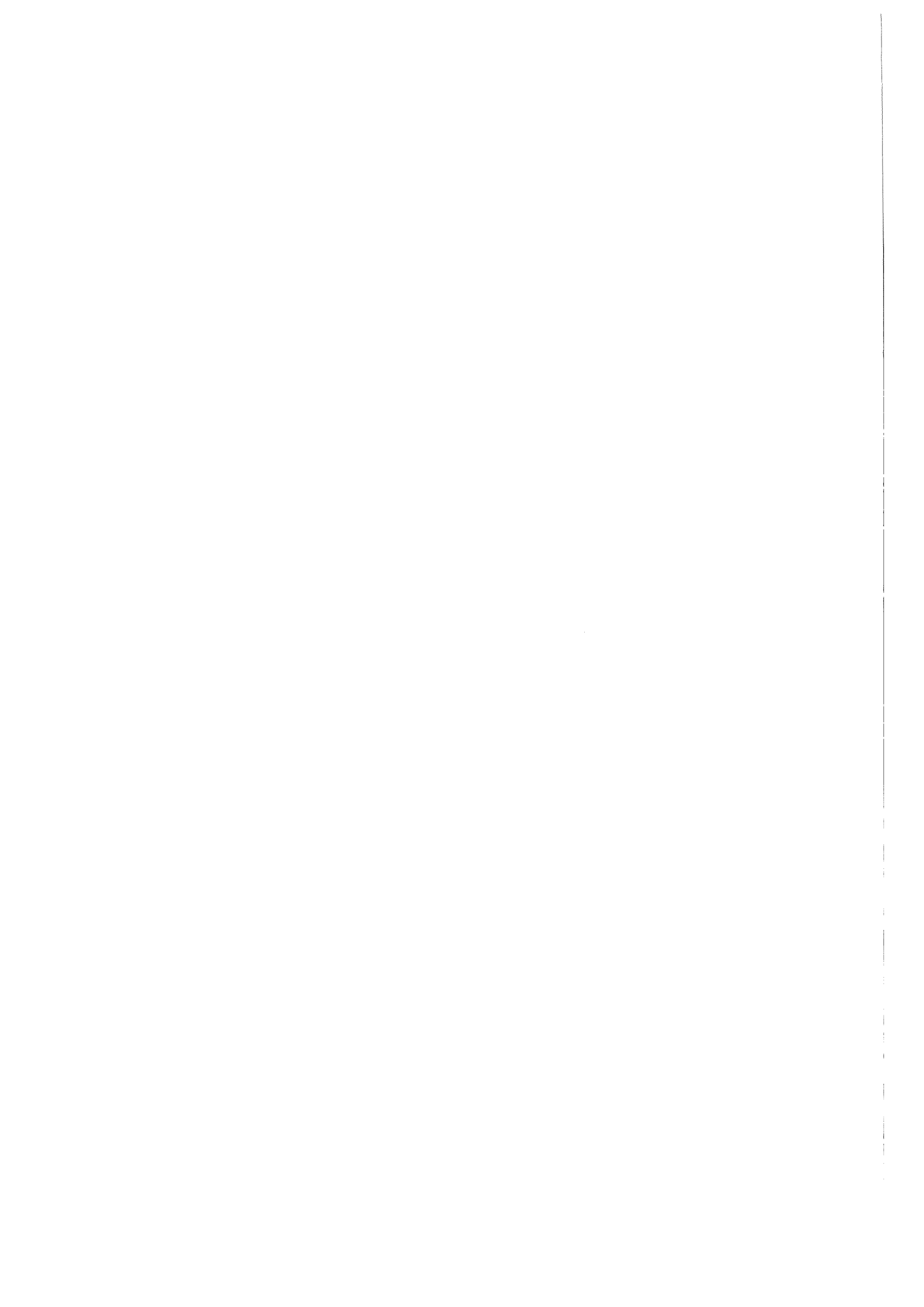
	TOTAL CALCULATED COSTS
MAX. NUMBER (M.U.)	0.5863E+10
MEAN NUMBER (M.U.)	0.1058E+10
SUM P <COSTMIN	0.0000E+00
FRACTILE 99.9 (M.U.)	0.5863E+10
FRACTILE 99.0 (M.U.)	0.4365E+10
FRACTILE 95.0 (M.U.)	0.3802E+10
FRACTILE 90.0 (M.U.)	0.2455E+10
FRACTILE 50.0 (M.U.)	0.6607E+09

CCFDS OF COST DATA:

	TOTAL CALCULATED COSTS
>= 0.2042E+08	1.0000
>= 0.2570E+08	1.0000
>= 0.3236E+08	1.0000
>= 0.4074E+08	1.0000
>= 0.5129E+08	1.0000
>= 0.6457E+08	1.0000
>= 0.8128E+08	1.0000
>= 0.1023E+09	1.0000
>= 0.1288E+09	1.0000
>= 0.1622E+09	0.9275
>= 0.2042E+09	0.9049
>= 0.2570E+09	0.8124
>= 0.3236E+09	0.7879
>= 0.4074E+09	0.7387
>= 0.5129E+09	0.6100
>= 0.6457E+09	0.5430
>= 0.8128E+09	0.4609
>= 0.1023E+10	0.3936
>= 0.1288E+10	0.2548
>= 0.1622E+10	0.2210
>= 0.2042E+10	0.1401
>= 0.2570E+10	0.0947
>= 0.3236E+10	0.0540
>= 0.4074E+10	0.0144
>= 0.5129E+10	0.0029
>= 0.6457E+10	0.0000
>= 0.8128E+10	0.0000
>= 0.1023E+11	0.0000
>= 0.1288E+11	0.0000
>= 0.1622E+11	0.0000
>= 0.2042E+11	0.0000
>= 0.2570E+11	0.0000
>= 0.3236E+11	0.0000
>= 0.4074E+11	0.0000
>= 0.5129E+11	0.0000
>= 0.6457E+11	0.0000

\*\*\*\* SUMMARY OF MEAN COST VALUES \*\*\*\*  
 \*\*\*\*\*

	FRACTION (%)	TOTAL COSTS
RELOCATION COSTS	46.53	0.4921E+09
DECONTAMINATION COSTS	10.54	0.1114E+09
FOOD BAN COSTS	34.77	0.3677E+09
EARLY HEALTH EFFECTS COSTS	0.60	0.6381E+07
LATE HEALTH EFFECTS COSTS	7.56	0.7990E+08
=====	=====	=====
TOTAL CALCULATED COSTS	100.00	0.1058E+10



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