Faculty of Economics, Business Administration and Econometrics

Serie Research Memoranda

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M. P. Misseyer*), E.R.K. Spoor*), H.J. Scholten**)
mmisseyer@econ.vu.nl; espoor@econ.vu.nl; hscholten@econ.vu.nl

Free University
Faculty of Economics, Business Administration, and Econometrics
Department of Information Systems*)
Department of Spatial Economics**)

De Boelelaan 1105, 1081 HV, or, P.O. Box 7161, 1007 MC
Amsterdam
The Netherlands
+31-20-4446056 (phone); +31-20-4446005 (fax)

Abstract

As responsibility for environmental policy in the Netherlands becomes more decentralized the need for environmental monitoring[1] at lower governmental authority levels increases. Although conceptual perspectives on environmental monitoring are abundantly available, governmental authorities lack effective application of environmental monitoring and supporting information technology. In this paper the authors propose a solution for implementing generic environmental monitoring instruments. The solution presented consists of three components. First, environmental monitoring is positioned in on environmental science and information science framework. Second, a data model named TASTE (an acronym of Time, Area, Substance and human acTivity referenced Emission inventory) will be described Third a hybrid management support system named EPM (acronym of Environmental Policy Monitor) will be described. We end the paper with a discussion of a project recently set up by the Inspectorate General for Environmental Protection[2] in the Netherlands. This project, in which an emission inventory data warehouse will be developed, is relevant to the study presented as it incorporates both the TASTE-model and the EPM-system.

[1] In this paper the term environmental monitoring relates to environmental policy rather than environmental quality. More concrete, overall emission inventory (environmental pressure) and emission reductions (environmental performance) are relevant issues in this perception of environmental monitoring.

[2] More specifically the *Department of Monitoring and Information* Management, which is abbreviated to MIM.

1. Introduction

In the last two decades mankind has made significant progress in tackling environmental problems. An impressive number of organizations, governmental authorities, scientists and environmental decision-makers have participated in smaller to large-scale research programs each of which contributed to the body of knowledge we now have on the environment, its phenomena, and their underlying processes. Because of our far more deeper comprehension of these underlying processes today we may have the power, at least take our responsibility, to manage and control human pressure on the environment. If we do not do so the globe, unavoidably, will be doomed to generations to come [2 1,4 1]. Since we started realizing this, in the early seventies, governmental authorities have been preparing drastic measures concerning environmental protection management and conservation [33-36].

This has not been different in the Netherlands, therefore the above description is well applicable to the development of environmental awareness in the Netherlands. Since the early seventies environmental management in the Netherlands has made a tremendous development; its national environmental policy - the new era started with the first national environmental policy plan 'To *Choose or* to Lose' [33] and the first national environmental outlook *'Concern for Tomorrow'* [25] - has been laureated within an international context Logically, because both environmental policy as well as the documents disseminate a new refreshing message[3]. Unfortunately, the euphoria of a decade ago has been overwhelmed by cynicism and scepticism. This because many of the progressive environmental policy targets (e.g. CO,, NO,, and NH,) defined have become too aggressive and absolutely unreachable. Although enormous volumes of information are being generated in the Netherlands with which governmental authorities should be able to evaluate and steer environmental policy, current practice is that most of the information generated is in some way or the other unusable.

In our view two problems exist that need to be solved First, we argue that there exists a significant gap between national environmental policy planning at the one hand, and regional and local environmental policy planning and environmental policy implementation at the other hand. In contrast with the national level at which information and knowledge on the environment as well as means and instruments for environmental policy planning and evaluation are abundantly available, at the regional and local governmental authority levels its lacks all of these issues for environmental policy implementation and evaluation. Second, we believe that environmental science and information science have been insufficiently integrated [8, 10, 19]. Such an integration is indispensable for generating relevant information and appropriate instruments supporting environmental policy and decision-making (planning, implementing and evaluating environmental policy). These two problems, obviously, are interrelated and therefore should be jointly addressed.

In this paper we will present a three-phase solution to the problems described above. First, we will provide a brief integrated view ofenvironmental science and information science. Secondly, using this integrated view we will be able to address the information need of the environmental policy and management field by proposing a generic information representation model. Thirdly, we will show in what ways this generic information representation model can be implemented into environmental management support systems addressing basic needs of governmental authorities at different levels in society, e.g. environmental policy planning versus environmental policy implementation (addressing the application gap). Naturally the solution is described from both theory and practice using the situation in the Netherlands. However, we believe that the problems described are not specific to the Netherlands, but rather global.

The remainder of this paper is divided into the following sections. In section two we will start with a discussion of our integrated view ofenvironmental science and information science. In section three the current environmental, i.e. emission, information infrastructure in the Netherlands will be described. Using an integrated view of environmental science and information science it will be shown that the national emission information infrastructure is not complete. Therefore, we have developed the TASTE-model descrii in section four, which complements the national emission information infrastructure. Next, in section five we will describe the application of the TASTE-model for environmental policy and decision-making. What we basically will do is to introduce the notion for (hybrid) environmental management support systems, which are required for environmental monitoring performed by governmental authorities. One of such systems that we have named the Environmental Policy Monitor, or EPM, will be described. In section six we will discuss the next steps in the implementation process of the TASTE-model and the Environmental Policy Monitor, which are more complex than they seem to be at first sight.

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[3] It is remarkable to see that the national governmental authorities in the Netherlands not only adopted the recommendations of international studies performed into national documents, but they copied the powerful naming of the studies as well, considering the titles of the reports '*The limits to growth*' [21] and 'Our Common *Future* ' [41].

Finally, in section seven we will draw conclusions and make some recommendations for future research.

2. An integrated view of environmental science and information science

Environmental science and information science share common characteristics. Both have evolved from the needs of society to be able to study and analyze complex issues and phenomena from different perspectives and to develop appropriate theoretical frameworks that could be used to address corresponding complex problems. In addition, both originated in the late seventies. With respect to the environment it became clear that most of the environmental problems were far more complex than they seemed to be; many of these problems often could not be dealt with individually but rather required an integrated approach [2,3,10,21,25,26,33-36, 41]. Concur-rently with the advent of environmental science information science emerged from the societal need to develop and implement a framework for translating the information need of organizations into appropriate information systems and subsequent information technology [9]. Since thennumerous (formal) models for structured system development as well as theory on information analysis and information management, and on information systems have beendeveloped Although environmental science and information science are applicable to complete different areas they have in common that they integrate physical and social sciences. Hence their nature is truly interdisciplinary.

In addressing, i.e. solving and managing, environmental issues and problems that put pressure on society governmental authorities prepare, develop and implement environmental policy. The major tasks of a governmental authority regarding environmental policy depend heavily on the position it has within the governmental authority hierarchy. National and provincial (state) authorities are primarily involved in environmentalpolicyplanningwhileregionalandlocalauthorities focus on environmental policy implementation. Although environmental policy planning and implementation tasks are performed at every governmental authority level they differ in planning horizon. Aside of these differences at every governmental authority level evaluation of environmental policy has to be performed that allows governmental authorities to adjust environmental policy whenever necessary. We argue that since the evolvement of environmental science in the seventies there has been an increasing clustering of governmental authorities around three main sets of tasks with respect to environmental policy (see Figure 1).

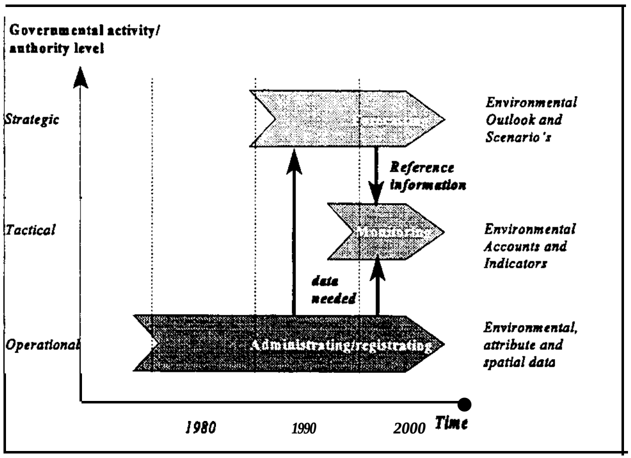

Figure 1. Governmental authority level with characterizing activity.

The fust and oldest cluster is based on ***administrating*** environmental issues and problems and on ***registering*** environmental pollution [38-40]. Although started at the higher governmental authority levels, today we may speak of a set of operational tasks because they are primarily performed at the lower governmental authority levels. The second cluster is based on the notion for ***forecasting*** future situations of the environment. The corresponding set of forecasting tasks has been developed in the mid eighties. Environmental forecasting enables more effective environmental policy planning and scenario development. Because of its complexity environmental forecasting is perceived to be ***strategic*** and therefore primarily performed at the higher governmental authority levels. The third cluster is based on merging subsets of administrat-ing/registering and forecasting tasks into a set of tasks suited for ***monitoring*** the environment, its phenomena and the effect of environmental policy defined. This set of tasks enables governmental authorities to (re)act within a narrow time span on new (unpredicted) events or on unfortunate developments respectively, for example by adjustment of environmental policy. Because the set of monitoring tasks can also be used to analyze and examine environmental pressure and environmental performance of governmental authorities, it is positioned at the *tactical* level. However, since its main purpose is to support implementation and evaluation of environmental policy, primarily lower, ranging from provincial (state) to local, governmental authorities use the set of monitoring tasks. The range from administrating/registering to forecasting and to monitoring is defined as ***the environmental policy activity*** spectrum.

The next step in a more integrated perspective of environmental and information sciences is to show their close relationship. In information science one of the ways of categorizing information is by looking at the level of aggregation (ranging from very detailed to very aggregated). Information in its most detailed form is raw data which can not be interpreted without being placed into its proper context. In contrast, an indicator or a construct which is the result of one or more data compression and data transformation processes, is defined as aggregated information. Hereby the level of aggregation depends on the scope of the indicator as well as on the number of aggregation stages passed. The type of information needed by governmental authorities involved in environmental policy processes may be expressed in terms of level of detail. This results ***in agovemmental authority information needspectrum***. According to this spectrum the scope of the governmental authority (level) corresponds with the information need, that is, national and provincial governmental authorities primarily need very aggregated information while local governmental authorities primarily need very detailed information.

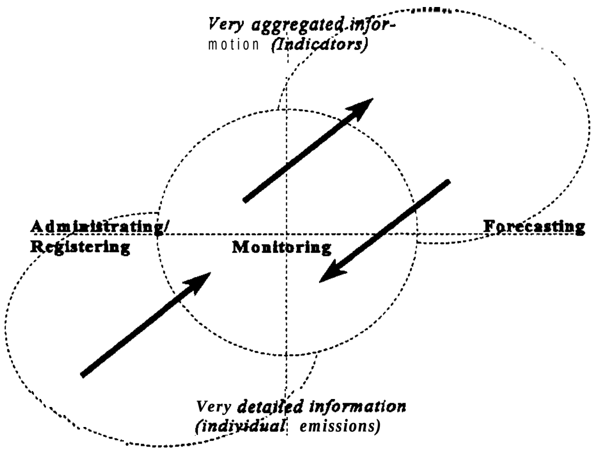

Figure 2. Relationship between the activity spectrum and the information need spectrum.

The final step for showing the close relationship between environmental and information sciences is by relating the governmental authority information needs and environmental policy activity spectra. Figure 2 depicts not only the relationship between the two spectra, moreover it represents an integrated view of environmental and information science (because the environmental policy activity spectrum stems from environmental science while the information need spectrum stems from information science). In administrating/registering tasks governmental authorities deal with detailed raw data and detailed information, in forecasting tasks they deal with aggregated to very aggregated information, and in monitoring tasks this varies. Furthermore the Figure shows a 'natural' path from lower to higher order tasks. That is, it is very important to see that both monitoring and forecasting tasks are complementary to administrating/registering tasks rather that the latter replaces the former type of tasks. Moreover, forecasting tasks can not be performed without administrating/registering tasks, while monitoring tasks requires both. That is, for every higher order task information ofgreater detail is needed to be able to aggregate further (arrows up). Also, as a specific case monitoring tasks need aggregated information as reference values. In many cases forecasting information will be appropriate (arrow down). Although not shown explicitly, forecasting tasks can obtain detailed information directly from administrating/registering tasks.

The integrated view of environmental and information sciences facilitates the translation of information needs into efficient and effective information systems and corresponding information technology. Administrating/registering tasks are best served with *transaction processing system or TPS functionality* and to some extend with *management information system or MIS functionality*, forecasting tasks are best served with *decision support system or DSS functionality* and monitoring tasks are *best served with hybrid management support system functionality* which is a combination of MIS, DSS and EIS[4]. Because the environment, its phenomena and underlying processes can often uniquely be characterized by their spatial dimension, the management support systems mentioned may be equipped with *geographical information system or GIS functionality*[5] as well. Underlying these management support systems a generic data model is required with which one is able to implode *(aggregate)* or expand *(de-aggregate)* information using the functionality of one ofthe management support systems without harming the validity or consistency of the data used (compare to [8]). In Section 4 we will return to the discussion of how the underlying data model should look like.

3. The emission information infrastructure in the Netherlands

The national emission, information infrastructure backbone is formed by the emission inventory information system, ER-C, is owned by the Inspectorate for Environmental Protection, an independent national governmental authority in the Netherlands. During the last two decades ER-C has evolved into an integrated environmental information system as it is able to provide an overall picture of the emission inventory in the Netherlands [4, 24, 38-40].

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[4] For an extensive discussion of general management support systems and corresponding information technology see for example [13,29,42].

[5] Ibid. environmental management support systems [8,10,12,14,17,18, 19 and 23].

In ER-C information on the emission inventory of 200 substances (emitted to air, water and soil) is registered on a yearly basis. Partially this is information on individual, i.e. point, sources (approx. 700 organizations for air, 1300 organizations for water, and about 3000 individual installations), and partially this is information on diffuse sources, i.e. all kinds of human activity, responsible for various types of environmental pollution [38-40]. Information on the diffuse sources is estimated using various statistics, demographic data and normalized emission factors and calculation methods [11,38-40]. The average resolution of information on diffuse sources is 0.25 km^2. Because ER-C itself is fed by data from a large number of (governmental) organizations at different levels in society, from an administrative perspective it can be seen as an integrating information system as well. Currently ER-C is used in the following tasks: first it is used for reporting on the annual national emission inventory, at a higher (national and provincial) governmental organization level [38-40]. At these levels such reporting can be used in ***environmental monitoring,*** although the information reported ***is (very)*** aggregated [40]. Clearly, ER-C ***is used in*** *administrating* and ***registering*** tasks at these governmental levels but not in ***environmentalforecasting tasks although*** in ***this respect*** it serves as a major data source[6].

Although not provided on a structural basis individual organizations, especially governmental authorities may obtain more detailed, or less aggregated, information from ER-C. However, provision of such information is bound to restrictions and depend on the manpower available. Consequently, it may take several weeks before information requests have been handled. Compared to the population, up to now only a small portion of organizations use ER-C in this way. Many of the information request relate to the ***administratinglregistering*** tasks of governmental authorities and industrial organizations. In some cases, mainly at the national level however, both research and governmental organizations use information obtained for performing ***environmental monitoring*** and ***environmental forecasting*** tasks. Looking at the foregoing we may conclude that ER-C serves (in)directly the entire environmental policy activity spectrum and information needs ofhigher governmental authorities, while, incidentally, lower governmental authorities use ER-C primarily for administrating/registering tasks. We may also conclude that the far majority of the (lower) governmental authorities is not aware of the possibility of using (aggregated) ER-C information for environmental monitoring purposes [22].

As we have pointed out in Section 2 environmental monitoring is the most recent development regarding environmental policy activities to be performed by, especially lower, governmental authorities. Because recent environmental legislation entailed to a large extent decentralization of responsibility lower governmental authorities are committed to monitor both environment and subsequent environmental policy (implementation). However, most of the lower governmental authorities do not have themselves such an indispensable information infrastructure nor the funds or means for developing one. Since the need of (lower) governmental authorities for (aggregated) information for environmental monitoring tasks evolved the adoption of sophisticated information technology in organizations (faster desktop computers, graphical user interfaces, integrated office software, Internet computing) has resulted in an even greater need for environmental monitoring information and support (see for example [8]). Moreover, the number of organizations and individuals in search for this type of information is increasing rapidly. Having pointed out that there is a great need for both environmental monitoring information and for means and instruments with which the environmental monitoring tasks can be served at the lower governmental authority levels, we will present next our generic solution.

4. TASTE: a generic data model for aggregated emission data

After examining environmental science literature and surveying the environmental policy and management field we found that to be effective a generic data model to be used in environmental policy and decision-making needs to be simple, robust and compact [5, 6, 8,22, 38-40]. In any case a generic data model to be used for environmental monitoring should be suited for storage of aggregated rather than detailed information. Therefore, the present national emission infrastructure[7] needs to be extended with two components. First, spoken in information science terms environmental monitoring requires a small data warehouse (compact data model for less detailed data) rather than large

6 For the Environmental Planning and Information System(RIM*), owned by the *Institute for* Public *Health and Environmental Protection* (RIVM), is the national strategic information system for development of national environmental outlooks (information on national forecasting) and national environmental accounts (information on national monitoring) [28].

7 Considered as the backbone of the national emission information infrastructure, ER-C, is not suited for environmental monitoring by lower governmental authorities because it is a very large (>100 entities, > 400 attributes) legacy system which was designed to support administering and registering tasks, and because it has a relative short time horizon (three years). For environmental monitoring a considerable longer time horizon is required (at least five but preferably ten or more years).

legacy information systems (complex data model for more detailed data). Second, such data warehouse need not only to be directly accessible but needs also to be accessible by specific environmental monitoring, i.e. hybrid management support, instruments (see section two) can benefit from it. In turn, such a hybrid management support instrument may be used by lower governmental authority management and environmental decision-makers to analyze and interpret the state of the environment, human pressure, as well as the effects of environmental policy [25, 26, 34, 36].

In ER-C information on the emission inventory is collected **and** stored in very great detail, with respect to both *location (source)* and *emission type* (which goes far beyond environmental compartment) [5, 6, 38-40]. With respect to environmental monitoring such a level of detail is unnecessary as aggregated information suffices. Therefore the first problem to deal with is to implement some ways of compressing the detailed information available. Here we go back to the basic dimensions with which emission inventory is referenced.

The first dimension, *TIME*, represent the *period of registration* which is defined in ER-C as the year of registration. The second dimension, AREA, represents a well-defined, bounded, *geographical area. In* contrast with ER-C point sources do not qualify because these represent detailed rather than aggregated emission inventory information. Furthermore, we do not impose restrictions on area type (geographical square versus govemmental authority *area). The* third dimension, *SUBSTANCE,* obviously represents the *chemical compound emitted.* The fourth and final basic dimension, *HUMAN ACTIVITY,* represents the *set of rather homogenous human activities* that causes specific pressure on the environment. As it is impossible to register emission data when dimensions are omitted we can truly speak of an elementary model referencing emission inventory information. The TASTE-model, see Figure 3, is named after its dimensions as the acronym stands for *Time, Area, Substance and human acTivity referenced Emission inventory* model.

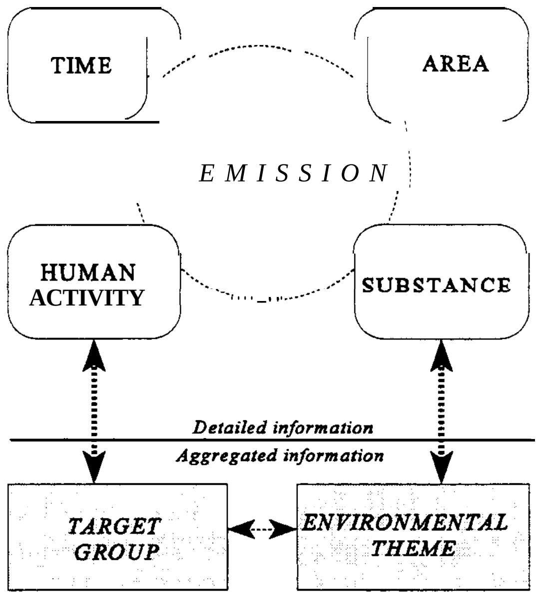

Figure 3. The four basic and the two additional dimensions of a high-level representation of the TASTE-model (see also Appendix A).

Once the basic components of the generic data model have been defined we still need to explain how the TASTE-model can be used in environmental monitoring. First we will discuss *the concept ofaggregation* using the TASTE-model. Second, *we* will show that *two additional dimensions* can be derived from the TASTE-modelthat are indispensable in environmental monitoring. Goal is to determine the lowest level of aggregation needed to satisfy the maximumnumberofgovemmental authority levels. That is, when the lowest level to be supported is the

Area Number	*Area Type*	*Human acTivity*	*Substance*	*Environmental Compartment*	*Quality*	*Unit of Measurement*	*Time*	*Amount*
321	M(unicipal)	00021	SO_2	A(ir)	D(ef.)	MTON	1991	23,399
321	M	00021	SO_2	A	D	MTON	1992	24,869
321	M	00021	SO_2	A	D	MTON	1993	34,123
321	M	00022	SO_2	A	D	MTON	1991	1,932
322	M	00021	SO_2	A	D	MTON	1991	56,799
322	M	00021	SO_2	A	D	MTON	1992	54,233
389	M	00099	N	W(ater)	D	KTON	1991	3,455
389	M	00099	N	W	E(st.)	K-TON	1994	5,100
389	M	00099	N	S(oil)	D	KTON	1991	12,343
389	M	00099	N	S	D	KTON	1992	13,243
389	M	00099	N	S	D	KTON	1993	11,234
2873	W(at. brd.)	00021	SO_2	A	D	MTON	1991	87,812
2873	W	00021	SO_2	A	D	MTON	1992	89,111

Table 1 Sample data formatted with the TASTE-model.

municipal level, the emission inventory information has to be aggregated to that level. For every substance, every human activity, every time period and every municipal area emission inventory figure has to be available. In fact, this needs to be further specified according to the level of detail required. Therefore, at least a distinction between environmental compartment should be included as well (see Table 1). Higher levels of aggregation should be obtained by aggregating information at lower levels. Except, when geographical boundaries between different levels of (spatial) aggregation do not perfectly fit information redundancy is unavoidable for those geographical areas at a higher level of aggregation. Because the number of areas at a higher level is significantly lower, such information redundancy is acceptable.

The second issue that needs to be addressed deals with the usefulness ofthe TASTE-model in environmental monitoring. This because the basic TASTE-model itselfwill not be sufficiently effective as it stands to far from every days practice in environmental monitoring and monitoring environmental policy. The main strength of environmental policy in the Netherlands lies not in the fact that policy has been developed for hazardous substances, for specific areas, or for individual sources. In stead, the integrated approach by *TARGET GROUP* and ***ENVIRONMENTAL THEME*** make environmental policy in the Netherlands unique [35]. These constructs represent the most important dimensions with which environmental monitoring is, and should be, performed. In the environmental policy framework in the Netherlands the target group and environmental theme dimensions have been defined as follows:

a ***TARGET GROUP is de*** fined *as collection, i e. aggregation, of human activities* [33],

an ***ENVIRONMENTAL THEME*** is a *collection, i.e. aggregation, ofsubstances* that cause the same environmental effect [34].

The power of the TASTE-model becomes clear as we see that both dimensions can be derived from the TASTE-model, see Figure 3. According to the above definition target group can be derived from the human activity dimension, whereas environmental theme can be derived from the substance dimension. The target group and environmental theme are the extended, i.e. policy, dimensions whereas the former four dimensions are the basic, i.e registration, dimensions of the TASTE-model.

5. EPM: a generic management support system for environmental monitoring

Availability of (aggregated) emission information via a straightforward implementation ofthe TASTE-model will not support the environmental policy and decision-making, i.e. environmental monitoring, processes ofgovernmental authorities. Although the information needs are essential to these processes, the need for appropriate information and policy analysis and evaluation methods are at least of equal importance. Therefore the third and fmal component of the solution exists of the development of a hybrid management support system. ***Hybrid*** because it needs to have a 'what-was' (*focus on the past)* or MIS functionality, a 'what-is' (*focus on the present)* or EIS functionality, and a 'what-if functionality (*focus on the short-term future)* or DSS functionality. ***Management*** because governmental authorities are held for responsible governmental management.

With respect to environmental monitoring environmental policy and decision-making processes are relatively straightforward because essentially insights are needed of (the development of) environmental pressure as well as environmental performance. This *can* both be obtained at *the registration level* (human activity, area and substance) as well as at the *policy level* (target group and environmental theme). Depending on the level of detail of the emission data collected and represented in the TASTE-model the concept of information (de)aggregation is a powerful aid for revealing patterns between different instances within each dimension at various levels of aggregation. This implies that concepts that for example originated from the business environment like management by exception, can be put into practice. Functionality could then be developed that only selects and presents information graphically of those area that do not show the same trend over time of the above, aggregated, area level. Then more detailed analysis can be performed to identify responsible target groups, or more detailed, human activity, if any.

Up to now the discussion, implicitly, dealt with generation of quantitative information at the individual substance level. Because in the Netherlands environmentalpolicy is predominated by the target group and environmental theme dimensions, an important issue is the generation of quantitative and qualitative information at the, aggregated, environmental policy as well. Therefore, in 1992 Adriaanse proposed for each of the environmental themes a corresponding *environmental policy indicator* at the Ministry of VROM [1, 30, 31, 34-36]. In 1993 VROM adopted *target group indicators* as well [1, 35, 36, 38-40]. Up to day, environmental indicators are mainly used at the national level or above*. In our view on environmental monitoring and given the fact that emission data is provided by the TASTE-mode1 we believe that environmental indicators can be used from the municipal level and higher. If the emission information in the TASTE-mode1 is relatively detailed, such as the municipal level, one is able to generate quite detailed environmental indicators for governmental authorities.

The only requirement is that the factors for substance contribution in an environmental theme have to be known and available. Both absolute emission information and environmental indicators can also be used in more advanced analyses. Depending on the availability of dimension characterizing data, e.g. population data, financial data(area and target group), toxicity, effects (substance), one can develop and perform analyses that adjust absolute figures into comparable measurements'. If such analyses can be performed over the years environmental performance of human activity groups, target groups, areas or a combination thereof, can be expressed as meaningful information.

Eventually the TASTE-model will be embedded into a hybrid management support system that we define as the Environmental Policy Monitor or ***EPM*-system.** EPM embodies the user-interface between the information stored and available for analysis, processing and visualization. Considering the original problems discussed EPM needs to be equipped with the following functionality:

Information function
Using each dimension of the basic TASTE-model one can be informed on emission inventory information at any (geographical) scale. Furthermore, one should be able to vary within dimensions and jump to related substances, area or human activities. Every selected set of information should be presented using a variety of presentation formats, both textual and (geo)graphical. A user determines the presentation unit for emission inventory information. This may vary from absolute figures, to indicators, or a combination thereof. Finally, every item of information or (selected) set thereof may exported;

Knowledge function
EPM needs to be equipped with a knowledge function. That is, using its graphical user-interface not only EPM should present a graphical overview of the TASTE-model, it also needs to be able to show the relationships of instances of dimensions chosen. This so-called knowledge function visualizes the representation of the underlying processes that are implicitly stored in the TASTE-model;

Analysis function
Among the more sophisticated functions are the analyses performed on individual dimensions or a combination thereof. The analysis function deals with the exploitation and exploration of the (aggregated) information available. This includes comparisons of governmental authorities with respect to policy performance, types of environmental pollution, development of environmental pressure over time (including corrected for population, human acTivity, costs) Also, short-term (l-3 years) forecasts are included in the analysis function. Obviously, the analysis function generates new information and knowledge.

Since the above description of EPMs (likely) functionality is rather abstract we need to demonstrate, conceptually, EPMs power and the many ideas we have on its functionality. Therefore, we will work out a short example.

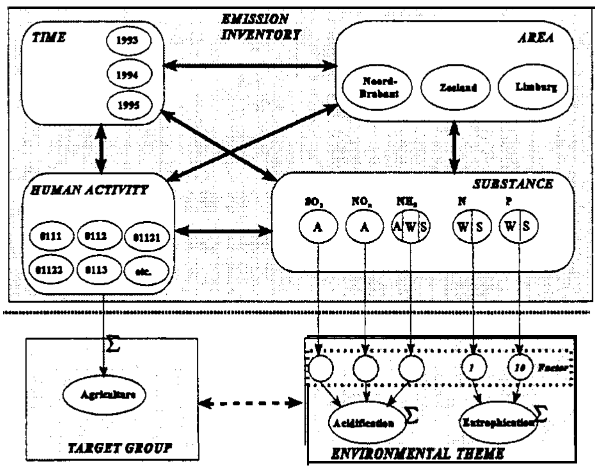

Figure 4. An example of TASTE/EPM with values for each of the dimensions.

Figure 4 shows an instance of the TASTE-mode1 which specifies the relationship of *the* target group *agriculture* for three years with respect to all human activity causing to acidification (substances SO,, NO, and NH_3 , and eutrophication (substances N and P) in three areas. Aside from a target group aggregation an environmental aggregation can also be performed. As some substances are emitted to more than one environmental compartment (A(ir), W(ater) or S(oil)) the relative contribution of each compartment can be separately analyzed as well. This simple example can be expanded into a more complex one by (1) including all municipal areas, (2) questioning the relative contribution of these areas to the higher governmental authority level, (3) comparing trends of each of these municipal areas, and (4) correcting measurements by rescaling to a common environmental pressure unit, e.g. square acres of farming land, number of inhabitants per area.

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8 From 1993 and on both target group and environmental theme indicators are jointly published in the annual progress, i.e. Environmental Program, reports [36].

9 With respect to ER-C a study on the aggregation of emission data has been performed by TNO, The Netherlands Organization for Applied Scientific Research [37]. In this study several alternatives and workable solutions have been presented for calculating, adjusting and presenting emission information aggregates.

Dimension	Scenario A. 1 Vector-based areas	Scenario A.2 Grid-based areas	Scenario B.1 Vector-based areas	Scenario B.2 Grid-based areas
Human Activity	approx. 200	approx. 200	approx. 200	approx. 200
Substance	approx. 200	approx. 200	approx. 200	approx. 200
Area	approx. 1,000	approx. 1,632 (5x5 km^2)*)	approx. 5.000	approx. 6.528 (2.5x2.5 km^2)*)
Theoretical number of records (per year)	40.0×10^6	65.28×10^6	200.0×10^6	261.12×10^6
Estimated number of records (per year)	$0.25\text{-}0.5 \times 10^6$		$1.0\text{-}2.0 \times 10^6$	

Table 2 Estimate of amount of information within TASTE/EPM. *) The Netherlands is based on a 240 . 170 km^2 area.

Depending on the minimum level of aggregation TASTE and EPM may, theoretically, contain a huge volume of information. In Table 2 we have provided some rough estimates of the amount of information to be disseminated [5, 6, 3 8-40].

As one can see in Table 2, theoretically, a vast amount of information on emissions needs to be stored, ranging from 40.0 to over 250.0 x 10^6 records. Fortunately, in practice only a fraction of this number of records needs to be stored as most of the substances are emitted at only a few specific locations (grids or within a governmental authority boundary). Although a TASTE/EPM implementation at a detailed (submunicipal, i.e. town, boundary or 2.5x2.5 km^2 grid) requires yearly several million records, using today's sophisticated information technology this is, technically spoken, no problem anymore and can be installed on a fast desktop computer equipped with sufficient storage.

However, iftechnical problems are an issue one may choose to provide only a information subset for the substance and/or human activity dimension, or to limit time dimension support (a limited number of registration rounds). We conclude this section with a brief discussion of the merits of an EPM implementation. Although there may be many more, we have found the following most important:

Flexibility
One of the most important advantages of EPM is its inherent flexibility. Using the simplicity of the underlying TASTE-model and only a handful of preprogrammed generic procedures a variety of operations, analyses and presentations can be performed. It will be relatively easy to expand functionality;

scope
The size of EPM is by far larger than any type of paper reporting ever will be. This because every dimension can be reported in much greater detail electronically. EPMs scope represents the core of the analysis function;

Representation
Acceptance of EPM is only guaranteed when EPM is equipped with a power graphical user interface (GUI) for analysis visualization (for both data model and meta model) and (carto)graphic presentations (trends, indicators, figures, tables, or a combination thereof). Therefore GIS functionality is indispensable;

Consistency/Accuracy
In contrast with traditional (paper) reporting EPM enables consistent reporting and facihtates updating and/or correcting information stored. In particular changes in underlying information, as a result of new insights or new agreements, are easily adopted. Even so important is the fact that the older information, when relevant, does not have to be deleted but can be stored as well. This powerful feature which makes EPM *backward compatible* is applicable to target group and environmental theme definitions, individual correction of emission information (estimates) caused by adjustment of emission factors and/or indicator factors respectively [11]).

Recently, for example, *chemical industry* and *other industry* **target groups** have been combined into the *industry* target group. Consequently, **older** information reported in annual reports can not easily be compared with new annual reports. Furthermore, combining the former industry target groups results in a loss of detail. Since information is stored from human activity, older target group definitions can still be used. In addition, using older human activity it is easy to aggregate this information using the new industry target group definition.

Furthermore we need to keep in mind that TASTE/EPM will be mainly developed for lower (provincial, regional and municipal) governmental authorities, because at these levels it lacks appropriate means for environmental policy and decision support, especially environmental monitoring. In contrast, at the higher governmental levels including the supranational levels major efforts have been taken to develop comparable instruments for environmental decision-makers and scientists [4, 8, 10, 17, 18].

After discussing how the TASTE-model should be embedded into a hybrid management support system, we have two questions left that need to be answered. That is, will the information infrastructure be extended with the TASTE/EPM environment?, and if so, what steps need to be taken for a successful implementation of TASTE/EPM?

6. Current status of TASTE and EPM implementation: the ERGO-project

In the fourth quarter of 1996 at ERIM a feasibility study was performed for developing an ER-C based emission information data warehouse [32]. The main goal of this emission information data warehouse would be the dissemination of emission (inventory) information to the professional public, i.e. organizations and individuals from the environmental policy and management field professionally involved in environmental monitoring. The ERGO-project, ERGO is acronym for its main goal, officially started with a kick-off meeting of the Guidance Committee at May 1 3th 1997. Basically the ERGO-project consists of three phases which, in chronological order are an *exploration/surveying phase* (spring 1997), a *design and construction phase* (summer/fall 1997), and *an implementation phase* (winter 1997 to summer 1998). After the first part of phase 2 a small working prototype will be delivered that can be tested by a selected number of organizations and individuals (September 1997). Depending on its quality as well as the acceptance of both ERIM and the environmental policy and management field the prototype may be implemented on a much larger scale in phases two and three.

ERGO and TASTE fit like pieces in a puzzle. The definition of the ERGO-project confirms the need of the environmental policy and management field for more detailed information, which we identified earlier as a problem (see section two). Also, the ERGO-project acknowledges the fact that the current ER-C information system is not suited to provide on a large scale information electronically since ER-C is a 'closed' information system (see Section Three). Consequently, the ERGO-project aims at developing, implicitly, *an* 'open' *data warehouse* on top ofER-C facilitating (user-directed) provision of information. This data warehouse needs periodically be refreshed with an ER-C data subset, with the restriction that because of several (legislative restrictions and governmental agreements) no detail data may be provided. Consequently, the ER-C data subset that is loaded into the data warehouse needs to have a minimum level of aggregation.

As our solution for tackling the environmental monitoring problem of governmental authorities (the TASTE-model/the EPM-instrument) merges perfectly with the need for an emission (inventory) data warehouse for information dissemination, ERIM has adopted the TASTE-model as the information (meta) structure for the data warehouse and the EPM-model as the functionality (meta) structure for the end-user application to be developed in the ERGO-project. Doing so, one avoids a rather technical discussion ('how' questions) and is able to concentrate on a content discussion ('what' questions). The content[10] discussion, obviously, focuses on each ofthe dimensions of the TASTE-model (e.g. level of detail of information) and EPM functionality (e.g. information analyses, presentation). Although it has not been decided formally to develop a full-blown version of the data warehouse, considering the discussions and presentations of the workshops, we expect that ERIMs management will decide to do so in the near future. When this decision is made, it needs also be determined to what extent (i.e. MIS, DSS, EIS and GIS functionality) EPM will be developed and made available to the environmental policy and management field".

7. Conclusions

We have found that the current emission information infrastructure lack support for environmental monitoring to be performed by lower governmental authority levels. This problem is caused by the lack of integration of environmental science and information science, that is, there is no integrating theory nor ate there appropriate environmental policy and decision support instruments available that support environmental monitoring and enables the construction of appropriate management support systems.

A confrontation of environmental science and information science concepts, i.e. the environmental policy activity spectrum and the information needs spectrum respectively, revealed that an integrated view of environmental science and information science has to be developed, for the benefit of more effective environmentalmanagement support(instruments). In this paper, as an example, we provided a practical solution of how the current emission information infrastructure in the Netherlands, in particular the integrated emission information system (ER-C),

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[10] In order to facilitate the content discussion (idea generation, investigating requirements, needs) a workshops was held June 18th 1997. Without knowledge of the TASTE-model developed before the workshop, workshop attendants derived and agreed upon about the same models ("what" and "how" questions). At a second workshop held September 4" 1997 the first data warehouse (TASTE) and interface (EPM) prototypes were presented. Although there was general approval the workshop attendants asked for more emission information to be available in the data warehouse prototype and, naturally, for more functionality (tables, graphs, trends, etc.).

[11] Given the fact that the ERGO data warehouse (TASTE) will be accessible via the Internet, the user-interface i.e. a Web-application, can be seen as the EPM instrument. But on the other hand a CD-ROM version of the data warehouse (TASTE) and the EPM instrument may be developed as well in the (near) future.

can be expanded to support environmental monitoring at the lower governmental authority levels.

This solution consists of a data model (TASTE), for storage of aggregated emission (inventory) information in a data warehouse using concepts like multi-dimensionality (time, area, substance and human activity, and target group and environmental theme aggregates), and a hybrid management support instrument (Environmental Policy Monitor) having necessary MIS, DSS, EIS and GIS functionality. Once TASTE and EPM have been implemented environmental decision-makers at different governmental authority levels will be able to retrieve emission inventory information for different geographical areas by (de)aggregation to the appropriate governmental authority level. Also, one should be able to calculate target group and environmental theme indicators from the emission information provided. This enables that emission inventories as well as environmental indicators ofresponsible governmental authorities both at individual human activity level as well as environmental theme and target group level can be analyzed and compared (which truly accounts for environmental monitoring).

Because major requirements of TASTE/EPM are simplicity, user friendliness and ease-of-use, we expect that it is likely that it will be adopted by the environmental policy and management field. Clearly, as the environmental policy and management field needs to work on more effective environmental monitoring better environmental monitoring instruments are required. In this respect the second step has been taken as ERIM has recently started the ERGO-project formalizing the expansion of ER-C and subsequent development of TASTE/EPM. A first working TASTE/EPM prototype is currently under construction. As soon as possible a selected group of users will not only be able to experiment with the prototype but is explicitly invited to join the discussion on TASTE and EPM functionality. Depending on acceptance tests and its success, a more extensive data warehouse (TASTE) and interface (EPM) will be developed *in 1998.*

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Appendix A: Global view of the TASTE-model