INFORMATION AND COMMUNICATION TECHNOLOGIES AND THE ENVIRONMENT: THE CASE OF THE TRAFFIC SYSTEM

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CONTENTS

1. INTRODUCTION

The potential of Information and Communication Technologies (ICT) to improve (or decrease) the "environmental performance" of the society is the main topic of this paper. The essay starts with the development of a framework by giving an overview about **main systems of ICT**, providing examples, which shall illustrate their general environmental relevance. Then it will be focussed on existing and possible **areas of business application** of these systems. A main emphasis is given to the particulars of the transport area. Having depicted this background, then the question will be raised, whether or to which extent ICT can make "**transport systems**" more intelligent in terms of the (critically discussed) rationality of the actors involved in these systems. Finally, some possible **environmental effects** will be discussed which may emerge as a result from the application of ICT.

2. A FRAMEWORK FOR INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT)

The issue requires to be structured by a framework for ICT and the environment. In the following, a categorization of different systems of ICT will be developed, keeping in mind that other distinctions by other criteria are possible. It has to be emphasized, that a task-oriented view is taken, emphasizing the **functions** ICT potentially has. The systems developed have applications in numerous fields of science and business. In order to point out the relevance of ICT for the environmental performance in the course of economic activities, examples for general environmental applications will be given.

It is extremely important to notice, that the types discussed below have to be seen as *components*, which can be (and very often are) an essential part of each other, rather than being independent and separate systems. On the other side, there is no strong hierarchical order, even if the listed systems are often built on elements of the former one. A database can be related e.g. to expert systems or the results of simulation models can be the subject of monitoring systems. This is also the reason why, although for some types typical examples can be given, technical solutions are not related solely to one system.

2.1 Control- and Monitoring Systems

Monitoring systems are used to automize the measurement of product or process performances. Monitored dimensions can be for instance emissions of environmentally relevant substances to spheres like air, water, soil over a certain period of time. They can be located at the source of the emission, e.g. attached to the emitting machines, at the borders of factories/plants, or they can monitor a larger geographical region. Monitoring systems are the fundament of **control systems**, which have certain critical states, thresholds or ranges integrated, which lead to certain measures (determined mostly by ICT systems described below) to be taken when the system gets out of the range defined. The rapid and steady increase in preciseness and also the improvements in terms of qualitative measurements, e.g. the detection of new environmentally relevant substances, enable the development of environmentally more accurate solutions.[1]

2.2 Information Collection and Representation Systems

Those are mainly systems, which collect gained data and transform it into one or several formats. This can be data e.g. provided by control- and monitoring systems as well as data, which covers legal regulations and requirements or other qualitative types of data. Conventional **databases** are the most common examples in this area. [2]

It has to be emphasized that, in general, these systems never work only "by themselves" but provide information for further purposes as the ones described below. This means that it is crucial, that users are enabled to have an overview about the scope, type and depth of existing data resources. They need "guidance", so called "meta-databases" (i.e. databases of databases). Several examples for environmental databases (of quite varying quality) within the World Wide Web are given in the Appendix. The huge number and quantitative and qualitative heterogeneity and dispersity of environmental databases illustrate the urgent necessity for purpose-oriented meta-databases.

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[1] for an overview, see Günther et al. (1995)

[2] Besides a rapidly increasing number of World Wide Web-sources there are many specific environmental databases presented in Guariso/Page (1994), pp.1-90 and Avouris/Page (1995); for a contemporary collection of climate-biased databases see Lautenschlager/Reinke (1997)

Strongly related to this, the very broad scope of the collected data creates a need to provide and to increase the **compatibility** of environmental information in terms of exchangeability and adaptability for further applicability within other systems. The heterogenity of empirical data, (as well as the data gained by modeling and simulation) mainly results from the multidisciplinary interest and relevance, as well as from the rapidly growing number of research projects all over the world, which are not only heterogenous in the methods applied, but also in the standards of the ICT involved. These inconsistencies have to be overcome at least to a degree, that ensures the easy exchangeability of knowledge. The main requirements of building such a compatibility can be categorized in terms of **content** (clear objectives, responsibilities, intended principal users, methdologies, contemporarity, etc.) and in terms of **form** (use of common protocols, compatibility with common software, etc.).[3]

Another developing area of data collection and representation cannot be ignored in this context. Thanks to the enourmous increase in the technological abilities of information processing as well as in the amount and the quality of geographical data (e.g. via satellites, improved cameras, digitalization of graphical information), so-called "**Geographical Information Systems**" (GIS) play a more and more important role in environmental applications of ICT.[4] GIS "...can be defined as a system for entering, storing, manipulating, analyzing, and displaying geographic or spatial data."[5] Three main elements of geographical data, points, lines (i.e. connections between points), and polygons (certain areas) can be distinguished. These elements can represent natural as well as man-made objects. Fed e.g. by aerial photography or remotely sensed data, the focused locations can be mapped in several ways, depending on the criterias, given by the objectives. By "overlaying" these so developed maps, environmentally relevant aspects (e.g. soil contamination through hazardous wastes) and their dependence and effects on other aspects can be illustrated.[6]

Most of the GIS have a modeling as well as a simulation component. This category is going to be described next. In this sense, GIS are another example for those systems of ICT, which integrate more than one of the functions described.

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[3] For a very good and environmentally specified analysis of data quality and compatibility see Carter/Diamondstone (1990)

[4] For a good overview see Congalton/Green (1995). The literature on this field grew vastly over the last years, whilst new fields of application are constantly explored.

[5] Congalton/Green (1995) p.9

[6] see e.g. Carrara/Guzzetti (1995), Lyon/McCarthy (1995) and Douglas (1995)

2.3 Analysis and Modeling Systems

Based on statistical analysis methods and modeling techniques, these models deal with the discovery of correlations between variables, and with simulation models, concerning possible developments in the future. In the case of GIS, the model would try to simulate (and thus try to predict) the spatial diffusion of emissions over time, based on different layers and hypothesis.

These systems represent one step beyond the "pure" collection of data. Dynamic components are added and impacts and the possible causes are analyzed. The rapid progress in processing capabilities supported these developments on this field as well. The central environmental importance of these systems results from the possibilities to transfer the usual "trial and error" of environmentally relevant actions more and more from the physical environment to the "clean" computer. An example is the ban of nuclear tests, accepted by most of the countries which possess nuclear weapons. It is mostly due to the fact, that explosions and further effects of these weapons can now be very realistically simulated at the computer, why the need for physical tests is considerably reduced.[7] Less spectacular examples, which are however still of high (and also environmental) relevance are the simulations used for aerodynamical optimization or for engine construction. Thus, obviously, the **design** process is profoundly changed by ICT, with a growing influence of environmental performance criteria to be integrated.[8]

Modeling and simulation systems are mainly **software** systems.[9] But they are, of course, still hardware „bounded“ and the progress of both components can cause tensions and problems. Hardware components are, e.g. for GIS, extremely expensive but nevertheless already obsolete after a relatively short amount of time and no longer state-of-the-art for the requirements of the existing software. This general problem

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[7] Unfortunately, the French government considered some additional „real“ tests at Mururoa in 1996 necessary, but interestingly, the justification for these tests was to gain crucial data, which would enable the military to carry out appropriate and sufficient simulations in the future, so that real tests can be avoided in the future.

[8] An extensive and partly highly formal overview of methods and areas of environmental modellation in terms of pollution-effects is given by Schnoor (1996), a broader range is covered by Farmer/Rycroft (1991)

[9] For an overview, see Grützner (1996)

appears here on a large scale and creates a main financial problem for users. The aspect of data-compatibility is crucial as well.

Most of the scenarios that lead to the understanding of environmental problems in the public did result from applications of this kind of tools and their abilities to „visualise“ and illustrate the impacts of anthropogenous activities on the environment. Thus they played and still do play an important role in the evolution of environmental awareness in society.

This key role in shaping the information leads to the question of quality and appropriateness of the technologies and methods used, not only in the environmental field. The appearently "untouchable" character of the results of such systems rely implicitly on the fact that these results are - at least in the view of the users at first glance - calculated by a "neutral" and "rational" machine. By doing so, the crucial fact is not considered, that the assumptions and the algorithms of which they consist, are "fully" man-made and hereby open for all kinds of imperfection, subjectivity and controversial scientific discussion. This leads to the need for considering always the either obvious or more "hidden" and invisible underlying assumptions of the models used in those systems, when looking at their results and thinking about so concluded measures.

2.4 Decision Support Systems

As in many other areas, the range of definitions of Decision Support Systems is very broad. They range from *all* types of systems, which support the process of decision-making (including sometimes even the coffee-machine) up to more strictly only computer-oriented systems.[10] The latter one, on which it is focused here, describes systems, which provide suggestions and evaluations for alternatives, their comparison and for specific measures based on existing informations. Here it shall be focused on systems, in which logical conclusions might be integrated. Such systems are the domain of knowledge based systems like - the most typical example - **expert systems**.[11]

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[10] see Janssen (1992), p.2,

[11] For an overview, see Hushon (1990). A not so recent but very comprehensive and condensed overview about the technology of expert systems, their benefits and limitations is given by Turban (1988)

Expert systems are part of the highly interesting (but at the same time controversial) research field of Artificial Intelligence. The heart of an expert system is its knowledge base, which is "fed" by an expert, whose specific knowledge in deep, but rare fields is implemented into this base by the support and intermediation of a "knowledge engineer", who "translates" this information in the language of the system. The same happens with the "inference machine", in which mainly heuristic rules and solution algorithms are located, which try to apply (i.e. give answers) the information from the knowledge-base to specific problems, which are given to the system as questions by the user via the user-interface.

Environmental applications of such systems started in quite narrow and specialized areas, but broadened in time.[12] One important characteristic of expert systems is the transparency of the rules applied, which made it draw a conclusion. This has a highly educational effect and value, which is of particular importance in the environmental area. Environmental issues are multidisciplinary, complex in nature and often outside existing educational contents, so that an additional educational need for managers involved in relevant decision-making processes is given, which may be (at least in a supporting way) matched by expert systems.

Limitations are clearly given here. To give the most important one: The obtainment-process of expert-knowledge can still be seen as a major impediment.[13] Firstly, the more deep and broad the transfered knowledge is, the more it takes time and effort to „dig“ for it, to refine and to store it, and secondly the possibility to transfer expert knowledge into a formal way and into terms, which are „understandable“ for the system, i.e. the so-called process of „translocation“ is limited[14]. The partly tacit nature and highly quantitative and normative character of knowledge contribute mainly to these problems[15].

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12 Hushon lists 68 environmentally oriented applied Expert Systems in 1990, see Hushon (1990); see also the examples in Denzer, et al. (1996), pp. 175-195 and Guariso/Page (1994), pp.211-268

13 see e.g. Davies, J.R. (1993)

14 see for an overview Müller/Prüfer (1988)

15 see Turban (1988), p.72

2.5 ICT as Media of Information-Flow

It lies in the nature of information and communication technologies, that the systems they create are necessarily **open systems**. They cannot exist without information (that is communicated in certain ways) from outside the system. Data processing inherently requires the existence of data – which thus has to having been obtained – from other systems or sources.

The main reason why a *network* is required lies in the fact, that in the vast majority of complex (and thus also environmental) management problems, none of the solution types described provides the required informations or answers *by itself*. For example data gained by monitoring or from a data-base represents the basis for interpretation and suggestions by an expert-system.

The heterogenity and dispersed nature of the components and of the information embedded within the communication networks shows obviously the dependence of information on communication technologies. The established links, the institutionalized types and ways of access become an integral part of the informations gained by these networks.

Governing these aspects, creating the design, establishing the relevant links or creating a forum and the opportunities to enable the systems to establish them themself, "administrating" this network by developing policies and setting standards makes plain the **necessity to cooperate** on the one hand but also to create an **adequate institutional framework** on the other.

It becomes obvious that ICT in terms of the technologies that exist, cannot solve environmental problems by themselves, they require coordinating and regulating support.

Clearly, by touching the regulation topic, a whole "can of worms" is opened. While the problems related to the degree and qualitative dimension of regulation of data transfer and access cannot be discussed here in general[16], this appears to be an issue, which has to be modified specifically for the area and the purpose of the network to be built.

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[16] see for an overview Hawkins, et al. (1995)

2.6 Integrated Information and Communication Networks

Integrated networks describe a „cooperation“ of all or some of the different types listed above. For a certain task, e.g. the general assessment of the environmental performance of a firm or a sector in terms of air pollution, a **specific and objective-oriented network** can be established. This can for example include an expert system covering the areas of legal and technical requirements, the use of databases concerning the air quality in the surrounding area, simulation models concerning the likely performance of a prototype, monitored data from existing pollution, etc.. Or, for instance, given the topic "CO2-level in the atmosphere", a detailed picture including e.g. its affection by deforestation, traffic and industry and its impacts on the atmosphere, climate, sea-level, etc. can be gained by using and connecting these systems. A network of various disciplines can be imagined which involves different institutions, sciences and business sectors.[17]

In this context, it is possible to expand the above introduced concept of meta-databases to "meta-information-systems", which play a vital role in establishing these networks; it is, in fact, a question of definition, since integrated information and communication systems can exist on more than one hierarchical level.

The application area in this paper, **intelligent traffic systems**, represents a highly environmentally relevant example of this category.

3. THE ENVIRONMENTAL RELEVANCE OF ICT IN THE TRAFFIC SYSTEM

3.1 ICT in Functional Business Areas

The entire process of creating goods and services can be regarded as a process of gaining, transforming and communicating **information**. Supplied goods, production processes the use of the product and its disposal are all creating social, economical, political, cultural and environmental **impacts**. The dimensions range from intended impacts - its "actual" performance - to unintended impacts, which become a problem

[17] A very comprehensive presentation on this subject is given by Fedra (1994)

when they violate existing values or people and the environment physically. To an increasing extent, the lack of information concerning the **unintended** dimensions is becoming a problem and creates the need to search for tools and means to gain them.

Information and communication technologies can help to achieve this task. The main functions were characterized above, in this section the specific possibilities in business, particularly in an overall traffic system, shall be analyzed.

Before focussing on intelligent traffic networks, environmental applications of ICT in business will be categorized, in order to help to put the network components later in the adequate context (main ICT systems, which appear specifically useful are indicated for each category):

- Information gaining ICT

These applications range from methods for market research concerning competitors and customers to the use of science and law databases. In the collecting and representation section of Chapter 2 examples for environmental applications were already given.

Main ICT-Systems applied ***Datacollection and representation***
Modelling and Simulation

- Production-process related ICT

Here concepts like Computer-Aided Manufacturing and Computer-Integrated Manufacturing are well developed concepts of ICT-application, on which Just-in-Time rely as well. Ford, as an example, recently started to create entire assembly lines virtually and thus is able to develop prototypes without even building them "physically".[18]

Main ICT-Systems applied ***Control and Monitoring***
Modeling and Simulation

- Design-related ICT

This is a traditionally highly ICT-related area. Concepts like Computer-Aided-Design (and partly Computer-Aided Planning) are established and full-integrated ICT-tools in this area[19], which are recently increasingly modified to improve the environmental performance. The powering of cars shows for instance an increasingly environmental dimension. After decades of pure prototype-existence, pure electrical and hybrid-vehicles (a combined powering of fuel and electrical powering) find an increasing presence in options to be chosen within traditional serial cars. ICT play an important role in many aspects, e.g. in the design of control systems for battery efficiency and use[20] and in chosing by itself or informing the driver about a possible selection between both powering systems, depending on certain parameters. The design-optimated aerodynamic of a car, which leads to its increased energy efficiency, is another example.

Main ICT-Systems applied ***Modeling and Simulation***
Decision Support Systems

- Site-specific ICT

These are systems, which monitor, control and regulate the performance of the processes of a specific site or plant related to certain criteria. Mostly, virtual criteria (efficiency and productivity performance) are combined with those of physical performance ("intended" output and "unintended", e.g. environmental output).

Main ICT-Systems applied ***Datacollection and representation***
Control and Monitoring

- Infrastructure-related ICT

These systems are an interface between products (and also processes) and the infrastructure they are embedded in. Examples are the connections of one site to another plant of the same company or of a site to a local pollution and accident monitoring system. In the case of the car, these ICT are the interface to the entire

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18 See Financial Times, 14.04.1997
19 See as an example for an extensive analysis of the implementation of these techniques in the production process of Toyota in Monden (1993)
20 OECD (1992) p.25

technological system, like municipal transport authorities, gas stations, retailers, other cars, etc.. These systems and their environmental impacts are in the focus of the considerations below.

Main ICT-Systems applied

Datacollection and representation
Control and Monitoring
Decision Support Systems
Integrated Information and Communication Networks

- Product-implemented ICT

These are devices e.g. for energy-efficiency control or devices that lead to another central area of ICT, which is the miniaturization of products themselves[21], with mostly positive environmental effects.[22] If complex product systems are included here, the field of intelligent buildings and civil engineering projects are included as well.

Main ICT-Systems applied

Control and Monitoring
Integrated Information and Communication Networks

As it was illustrated, ICT are covering an enormously wide scope of purposes. There is a close interaction between organisational and strategical level of objectives. ICT are a medium to optimise the flow of information within the company and between the company and external institutions (organisational objectives). But they also serve as a tool for the development and implementation of elements of corporate strategy (strategic objectives).

[21] Freeman (1992), pp.200

[22] Considerations concerning the ratio of positive and negative environmental effects lie in the heart of discussions in environmental politics and environmental economics, mainly in terms of variables, criteria and, mostly important, of the methodology used; thus they, in fact, depend on the entire philosophy behind a scientific approach. The discussion of such aspects, even only in parts, require at least an own paper and thus will not be carried out in a more elaborated way here. In this paper, only a broad and functional definition of positive environmental effects is given at the beginning of 3.2 below, where the historic and evolutionary context of such assessments will be acknowledged.

3.2 An ICT-Application in Business: Intelligent Traffic Networks

A great number of overall traffic systems with ICT at their „center" have already emerged all over the world.[23] Several Research Projects within the 4th Framework of the European Union deal with so-called „Telematics" (a combination of *tele*communication and infor*matics*) and several areas, among them Transport. Furthermore, the European PROMETHEUS Project, a joint effort of car manufaturers, suppliers and research institutes tried to explore the opprtunities of Intelligent Traffic Systems on various levels. This unique project illustrates also, that this area is very suitable for such cooperations, since Intelligent Traffic Systems might be considered to be in a „pre-competition" phase, in which participants have a good chance to become well-prepared and in the forefront of the developments when it will come to set standards and the infrastructural frame. However, the activities concerning Intelligent Traffic Systems are very heterogenous, in regional and inter- and intrasectoral terms as well as in terms of research.[24] Thus there is the need to find a kind of „common-ground" for discussion concerning at least the questions, which have to be asked and the tasks to be defined. This paper attempts to contribute to this search from the environmental point of view.

ICT and its impacts to the traffic system emerge on two levels. On a **planning level** in road building and modifying[25] and (partly considering this) in planning the adaptaion of such systems by the development of car-implemented items by the car industry[26]. And secondly, related to the use of these systems, on the level of **"live" surveillance and control**. [27] On the first level, mainly modeling and simulation systems are used (on the basis of collected data and estimations concerning the overall developments in traffic). The second level appears to be of greater interest, not because new projects, i.e. the planning level, would appear to be environmentally

[23] see Polydros/Panagiotou (1997), pp. 185ff., especially for comparsions of Europe, North-America and Japan

[24] As an example , the recent international workshop „The Automobile of the Future" , held in Wuppertal by the Institute for Climate, Environment and Energy on the 2-3 March 1998 showed that the current discussion is far away from a concensus concerning even the perception of problems, and that huge gaps in these terms exist even *within* firms or research institutes or governing bodies.

[25] see for instance Ioannou (1997) for an overview of Automated Highway Systems

[26] Within the format of this paper, a detailed analysis of particular techniques can not be given, but for a quite extensive elaboration, see for instance Nwagboso (1997).

[27] see e.g. Catling (1993) and applications given in Dailey/Haselkorn (1995), pp.475-497

irrelevant, in contrary, they have a significant impact. But the vast number of roads and related infrastructure, which are already built, and the problems resulting of the current use of this existing system are demanding for the urgent search for solutions, which can be adapted to the existing structures.

Perhaps the most important field of ICT in traffic is related to "intelligent" road information and communication systems, which represent the second level. This importance stems especially from the fact that they represent an overall system, within which a lot of subsystems - not only road traffic - can operate. It appears to be useful to look first on the aspects, which created the need for these systems, or which made it "unintelligent". In fact, the problems result from the phenomenon, that the entire system of transportation has shown a rapidly growing number of **inefficiencies** in the course of its emergence and development. Concerning environmental aspects, the definition of efficiency brings us to a crucial point. The degree of efficiency of a system is always defined by the needs, expectations and related aims of the users of the system, thus it is evaluated from a **preference-bounded** point of view. The importance of this notion simply cannot be overestimated. This means implicitly that considerations concerning efficiency is linked to the evolution of the **rationality** of the users, which are imperfect and are only of a bounded rationality in nature.[28] The ideal towards which the system of individual transport should move in the eyes of the users has been mainly the free, i.e. without any major disturbance or interruption - access to the point of destination at time and at acceptable costs, with the „acceptability“ defined through (heterogenous) preferences as well. This represents the yardstick for the efficiency of the system. Traffic jams, the degree of affection by weather conditions, road works or inadequencies in the linkage to other transport mediums (like air transport) were seen as obstacles for achieving these goals. User **conveniance** is a crucial point.

An overview shall be given in the following table about the different fields of application areas, in which improvements towards an increase of the so-defined efficiency of the system are envisioned, while it should be focused on environmental consequences more than on technical details. The main elements for every area are highlighted. On each level, specific road control management provides information for travelers/drivers in close interacton. The list is not exhaustive and varies significantly in time:

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[28] The discussion of the fundamental implications of this notion on environmental policy would exceed the dimensions of this paper. For some intellectually stimulating starting points see e.g. Beckenbach (1991) and Bauer/Matis (1989)

PRIVATE AND BUSINESS RELATED INDIVIDUAL TRANSPORT AREA	TRAVELER INFORMATION	***Journey-related and journey-optimizing information*** - trip planning - advisory - position location systems - navigation - gas and accomodation supply information - touristic information systems - maps - traffic information (road works, traffic jams, general traffic density) - real-time route guidance systems - inter-transport-medial suggestions
		Vehicle-related information - information about critical dimensions (brakes, oil, temperature, etc.) - energy consumption and efficiency - parking help systems - collision warning - automatic breaking systems - seat belt fastening warnings
	ROAD CONTROL	- traffic network monitoring - geographical information about pollution - parking management - incident detection and management - infrastructure to distribute these informations to where and when the users need them (need detection)
FREIGHT LOGISTICS AREA	DRIVER-INFORMATION	- vehicle, cargo and destination monitoring - communication of changes in traffic conditions and receiver preferences
	ROAD CONTROL	- intermodal transport planning - route planning and scheduling - hazardous material monitoring and tracking - vehicle and cargo monitoring - monitoring of the destinations and their needs with minimization of the reaction time - breakdown and incident monitoring - logistic incident reaction optimization
PUBLIC TRANSPORT AREA	DRIVER- AND ON-SITE-STAFF INFORMATION	- passenger dynamics and location - information about interaction with other transport-media
	ROAD CONTROL	- dynamic planning and scheduling systems - automatic payment systems - arrival/departure information system - general traffic monitoring

TABLE: AREAS OF APPLICATION OF ICT IN TRAFFIC SYSTEMS

It is crucial to see these areas as overlapping, because otherwise they lose their efficiency. When freight tansports are not informed about traffic jams, which are mainly caused by vehicles from the other areas, it will be stuck as well. Public transport vehicles have to know where the need is, which is partly determined by short termed developments in the individual area. Thus these areas must be part of the same system, while the focus on specific needs of every area must be sustained.

ICT is also essential for this kind of "cross-sectional" data transfer. Several **technologies** are partly already used in existing navigation systems or are candidates for those in the future. The most important ones are[29]:

- **Short Range Radio**

- **Subcarriers**

  Examples are **R**adio **D**ata **S**ystem (RDS), Secondary Auto Programming, High Speed FM Subcarrier Data Systems

- **Roadside Beacons**

- **Digital Cellular Systems**

  Those cellular systems were planned for voice transfer but the utilization for a variety of data services is planned

- **Personal Communications Systems**

- **Mobile Satellite Systems**

  Lower Earth Orbit Satellites must be redjusted but have the advantage of being closer to the earth surface and thus can be positioned more precisely for local needs, they often interact with other satellites

- **Satellite-Based Position Location Systems**

  The most popular recent example is the **G**lobal **P**ositioning **S**ystem (GPS), using 24 satellites in 12-h orbits and providing already many services

[29] Based on Poloydoros/Panagiotou (1997), where details about frequencies, applicability and further technical details are given.

All systems are applicable to the areas above to a different extent. Some of these systems are quite well developed. This reduces the institutional barriers to introduce traffic networks, because they provide the infrastructure in which intelligent traffic networks can grow.

3.2.1 Intelligent Traffic Networks and the Environment

The question now is, where the overall picture, which was depicted up to this point, will lead to in **environmental** terms. Of course, in this paper, this question can only be started to be answered.[30] The description of the technological context, conditions and opportunities has been carried out that elaborately in order to provide a reference framework as a **platform** for a thorough discussion. In this sense, this paper intends to be a „discussion paper“ in a quite literal sense, since it only can provide **starting points** for a scientific discourse – especially supported by empirical analysis -, which shall be encouraged hereby.

Thus, only more „**essayistic**“ remarks shall conclude this paper. As we have seen, rapidly increasing opportunities to optimize traffic by intelligent traffic systems are emerging. Thus, the traffic will shift towards a higher degree of „efficiency“ in the above defined sense. But the expectations from the traffic system are increasingly **complemented** by the need to **change** the environmental impacts of this system. The use of the term „change“ rather than „reduction“ is intentional and important, even or especially because it is „only“ in a more subtle way. Reduction of **existing** environmental impacts, of course, appears to be the most obvious complementation in preferences. But in reference to the crucial notion that environmental impacts of socio-cultural activities of some kind are in principal inavoidable *per se*, it has to be recognized that a reduction is „not enough“. It has to be accompanied by **qualitative** considerations, which try to find ways of anthropogenous activities, which make in terms of their qualitative nature the - at least to a certain extent - inavoidable effects more compatible with the environment.

However, the definition of efficiency is changing, in other words, the „yardstick“ contains a new dimension. It has to be remembered that, in general, todays ICT applications were initially not developed primarily in order to reduce - or change - the

30 For a general overview as well as an elaborated discussion of integrated traffic concepts from an environmental perspective and thus beyond the relevance of ICT in particular, on which it is focussed in this paper, see Müller/Schwenke (1992)

environmental impacts. Whether and how far this can be achieved, is the subject of the concluding discussion in this paper.

To discuss this question, the **consequences** of an increased introduction of intelligent traffic systems must be estimated and - based on that - their environmental effects. As „positive“, environmental effects are considered, which lead to a reduction or change of environmental impacts, which are assessed and perceived as negative.

Here, a remark is necessary concerning the „evolutionary character“ of such assessment criteria. What is perceived as environmentally „good“ or „bad“ depends on existing values and preferences which are derived from socio-cultural and scientific developments. What is supposed to be emphasised here, is that the „positivity“ reflects only a subjective rationality, because it is bounded to preferences, which are subjective and subject to change in time.

3.2.2 Individual Area

On the **individual** level, the effect of a better traffic flow and a decrease in traffic jams as an effect of intelligent traffic systems can be derived. In environmental terms, several effects, positive as well as negative, might be considered. Because of the fact, that the pollution by cars is increased significantly with the number of starts and stops, a more fluent traffic flow leads to pollution reduction and thus to a positive environmental effect. Apart from that, the drivers can terminate their journey faster, and thus are on the road (and polluting) for a shorter amount of time, as long as the alternative routes, which are taken, are not too much out of the initially planned way (i.e. compared with the pollution in the stuck traffic). With navigation systems, the search for unknown adresses is shortened as well.[31] As another example, Siemens recently introduced a concept for the solution of the problems concerning the required space, the time „wasted“ by searching for parking spots and the so caused additional pollution related to parking in urban areas by offering the possibility to „reserve“ parking spots in the city via the Internet before the start of the journey.

[31] Volvo, in cooperation with Blaupunkt, recently presented the first navigation system, which takes traffic jams into account. Through RDS, and contact to three LEO-satellites the traffic-information is digitally processed and integrated into the navigating computer. The prices for such systems are continually decreasing.

However, these opportunities are ambigious in nature. It can be argued now, that as soon as the traffic flow is fluent, this will lead to an increase of the *de facto* capacity of the roads and to the attraction of more cars to the roads, and that thus the reduction in pollution might be compensated for. Whether this is supposed to happen or not, is very hard to predict – and maybe even harder to proove, because of the complex causal relationships which „determine“ the amount and fluctuations of traffic. Part of this complexity is the relationship between the car to other means of – mainly public – transport. It has to be investigated, what creates the need for people to travel, and if they travel, what makes them pick a car or another medium. Surely people are attracted to driving more when traffic is less jammed, but this is not the only criteria that makes people decide whether they chose the car as a medium for transport or not. More important seems to be the sheer increase of the number of cars over time. Even if the traffic situation, especially in the cities, is considered as problematic, the mobility gained by the car is likely to sustain its attractivity.[32] This involves the area of „car-psychology“, which develops a „rationality“ of its own. It is crucial that such **institutional aspects** are considered as well when thinking of technologies and their **appropriability**.

However, this means that, in the end, the traffic system will face a growing number of vehicles. Thus it can be assumed, that intelligent traffic networks will not lead to an **absolute** reduction of pollution, only by providing more fluent traffic. The question whether a relative **reduction** can be expected - that is to say, the increase of pollution would have been higher without the increased fluidity of traffic - depends on the ratio between the changes in efficiency and the growth rate of the number of vehicles and the change in the quantity the use of the vehicles, which might be measured in kilometers driven per person within a certain amount of time.

But the pure fact that more vehicles exist does not necessarily lead to a "lock-in" of this situation. Intelligent traffic networks have an enormous potential when it comes to **inform** people about the most efficient way to travel. The best solution can only be found, when „really“ all alternatives are considered. This is meant in a way, which expands the alternatives to satisfy the need of the user for transport to other means than - in this example - the car, **more**, than this would have happened without ICT. Intelligent Traffic Networks possess the potential to realize this, by including, for instance, the alternative of public transport into consideration. This is a decisive one, especially in the big cities. An intelligent network, which links public and individual

[32] See Womack/Jones/Roos (1990)

transport could inform the driver about the best alternative to travel for the **specific situation** in which he is in at a certain time. The data about the current traffic situation on the road **and** of the public sector would be assessed **simultaneously** on-line by a decision support system. Based on the decision criteria it would "calculate" the best alternative (or several alternatives by explaining the priority for each), by considering the current state and predictions for **both**, the private and the public network. This (or these) would be transmitted to the user, who could decide, which transport medium they chose. As the Siemens example shows, practical solutions might be less complicated than these considerations may sound. The simple information that no parking spots are available for reservation implies already the beneficiancy of other transport means. The user might be offered those alternatives in the shape of time-tables directly via the same Internet-service. The great advantage of ICT in this context wuld be its individuality, i.e. the possibility to to develop individual solutions for the specific needs for one user.

Such an intelligent network would have a terrific environmental potential, under the (crucial) condition, that these criteria include environmental aspects. Furthermore, the transmission to the user must contain explanations in order to increase the "acceptance"; various forms of expert systems could provide this (see above). This could be a way to decrease the traffic **on the road**, and thus pollution, despite the increase in the number of vehicles.

These network solutions have to be complemented by vehicle-related components. To communicate within the network, the driver needs an **interface**[33], which graphically or verbally represents the data received from the network and which has educational implications which will be emphasized in the concluding part of this paper.

In addition to this more external communication device, ICT plays a decisive role in communicating environmentally relevant data from the car itself to the user. Fuel-efficiency depends to a certain degree on the style the car is driven. By showing on the display i.e. when the fuel-consumption (and pollution) is increasing, the environmental awareness (whose existence is assumed here) can be appealed to. The level, on which the range is set, within which these gains can be realised, is determined by the characteristics of the powering, the weight of the car, its aerodynamic characteristics, etc.. The environmental contribution ICT can make on the field of design was already mentioned.

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33 See Kirson (1995)

It becomes clear, that ICT can represent a powerful tool to **increase the rationality** of the users of the system, also in environmental terms. However, although any improvement in environmental performance is important, the "mass effect" of a growing number of cars is likely to overcompensate these improvements as well, so that here also only relative environmental advantages can be expected. While the fuel-efficiency (especially after the oil-crisis) improved a lot and although some cars are below the 3 liter mark per 100 km, it appears to be very doubtful whether the mass effect can be stopped.[34]

Thus the focus has to shift increasingly towards a **qualitative alteration** of the way vehicles are powered. More and more cars with at least partly electrical powering are introduced. After famous prototypes like the Ultralite car by GM,[35] firms like Volkswagen, Audi and Mercedes[36] offer such cars, too. The case of the hybrid car is of particular interest, because the ICT implemented decides about when which powering is used, mainly through control- and monitoring systems. Hybrid cars usually use fuel powering on long (and usually jamfree) distances and meanwhile load the battery which is used as a power source on short-distances (e.g.cities). The contribution to the environment is enormous, because most of the pollution occurs on the most frequently done short distance drives. ICT can help maximizing the use of the electric powering, and thus help to reduce pollution. In case of the driver deciding by himself, it can show him how to do this. Thus the altering of powering supported by ICT can fight the "mass effect".

Those were only a few examples for the environmental contribution of ICT in the individual transport area. The examples given could be extended easily to interregional and international traffic. The thoughts were described consciously in an essayistic way in order to stimulate the discussion. Some brief considerations for the freight and the public level, which are given in the following shall complement these thoughts.

3.2.3 Freight Area and Public Transport

In the **freight area**, ICT provide crucial links not only concerning the position of the

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[34] See Lovins/Lovins/v.Weizsäcker (1996), pp.33ff.

[35] See e.g., Roy (1994), pp.367 or Lovins/Lovins/v.Weizsäcker (1996), pp.35ff.

[36] Mercedes will offer an electric version of its new small Smart-Car in 1999. Audi introduced the new Audi Duo recently, offering three alternatives, electrical, gas or combined.

vehicles with the above introduced surveillance systems. It also enables the monitoring of the freight, and the steady information (e.g. about temperature) transfer to the central control. Especially for sensitive goods, like food or dangerous hazardous goods this is a great improvement. Geographical Information Systems are applied massively in this field. The environmental improvement is obvious: hazards monitoring has improved significantly through shorter reaction times to accidents. Apart from this, waste (e.g. of food) is minimized as well. The shorter reaction time to new orders reaching the central unit, is also an environmental advantage: the unit knows where the nearest vehicle with the required goods is, and the driven distance is minimized. These areas illustrate the logistical potentials (and thus the potentials of reducing the damages to the environment) of intelligent traffic systems in the freight area.

ICT in intelligent network systems are a major tool to **increase the efficiency of public transport** systems. The road navigation system is of particular relevance for buses, especially in order to avoid over crowded routes, because travel times would be shortened. Links to other transport media like trains or airplanes can be established, so that passengers always - also during the journey - know about the connections. The possibilities of data collection enable to locate the need for transport and to react faster. [37]

In general, the attractivity of public transport, with its undoubtedly positive environmental effects, has to be assessed in relative terms, i.e. in comparsion and interconnection with the individual area. Both systems have to complement each other and ICT promise to become an **interface between these systems**, its contributions were already discussed above.

4. CONCLUSION

It can be concluded, that ICT have undoubtedly an enormous potential to reduce and change the environmental effects of traffic. It can increase the rationality of the people and institutions involved in the „system“ of traffic towards a more environmentally sound behaviour and „outcomes“. But in order to realise this potential, a coordinated interaction between several heterogenous levels and actors is required. The levels involved which are affected by the use of ICT range from vehicles, their equipment

[37] Chou (1995), pp.352ff.

and powering to local and „global“ transport infrastructures and traffic management. In respect to this the heterogenity of the involved actors is obvious: the **individual as a user**, the managers of the **car and the fuel industry** (i.e. the suppliers of „traditional“ *and* alternative fuels) and, on a policy level, **local and central transport administrators**.

As it was shown, ICT can increase the environmental efficiency in the above defined sense not only of the **components** of the system but also in terms of **coordination of these components**. This coordination creates necessarily several interfaces, which – beyond questions of technology – through aspects of their quality, appear to be crucial for the success of policy measures. ICT can be useful only to the extent the suppliers and the users are **willing (rationality aspect)** and **capable (educational aspect)** to benefit from these potentials. This leads to two important aspects, which appear to be vital and which shall conclude this paper by hopefully stimulating further research.

The **educational aspect** was always important in ICT applications, but with the widespread implementation of ICT in **mass-produced** goods, it has got a new dimension, because a large part of the present or potential users have none or no sufficient background in dealing with ICT. Several aspects, which appear to be decisive, shall conclude this paper; again as an encouragement for further discussion:

Are the users able handle the devices?

Using a navigation system means using a small PC. One has to consider the extremely varying range of quality and depth of educational and experiential **backgrounds** of the users, when such systems become an integral part of a car as a **mass-product**. ICTs potential can only be exploited when it is properly handled. This means that the accompanying **information policy** must proactively adjust to such a broad range of needs in the design of the product, the manual, hot-lines and concerning the role of the retailers.

Are the users able to understand the information?

Even if it is considered that people can use the devices, another decisive question remains: Can the users realize the content of the informations provided by the devices?

This question is easy to answer for the case of the information how to avoid a traffic jam. But a certain degree of fuel consumption or the criteria that led to the calculation of the other route, which is environmentally friendlier, can be harder to understand and evaluate. Thus, the information given must be explained, with supporting data, graphical elements, or verbal explanations, so that people with a different educational backgrounds and - as a result of this - with different systems of notions, values and attitudes can become aware of why the system provides that particular information and why which alternative might be beneficial in which terms. This point illustrtates very well the basic need for interdisciplinary research, although this expression has unfortunately become already a kind of „scientific buzz-word". But policy in a complex area like traffic is condemned to failure if it does not integrate for instance psychological, educational and socio-cultural considerations in addition to engineering and statistical aspects. And this is not only valid in terms of users but also of the multi-level process of decision making.

Do users know about the impacts of their actions?

Thus an educational background at least about basic assumptions concerning the impacts of the actions of the users is required. Environmental awareness often shows the phenomenon of a sharp **discrepancy** between the **level of attitudes** and the **level of actual behaviour**. When people are asked whether it would be a good thing to use more public transport or drive less in general, they are very likely to agree. But when it comes to act in these terms, the **rationality** is often different and bounded. The system must clarify the advantages, which result from the actions, which are implcitly or explicitly suggested by ICT. Thus, ICT is a subject of bounded rational behaviour, but at the same time it is a mean to overcome it. User-friendliness and a higher transparency about the way the systems work, is important for the commitment of users and in the end of its **acceptance**, which is a vital factor for the success of every network. The educational as well as the rationality problems are easier to handle in the freight and in the public area, because of the limited number of users, which can be trained more easily.

What is the role of the interface?

From this point of view, the user interface can be considered as the most important component. It can be considered as a window to the inside of the system and determines the views, attitudes and acceptance of the user. The technological capabilities described can unfold their potential in general as well as in the environmental field only, if the needs and requirements of the people using it, are considered. This can be achieved best, if these considerations are integrated in the design process as early as possible. This requires the start of environmental education already at the designer / engineer level as well as their cooperation with administrators and lead-users from the start. Thus, this group has inherently a key function. They must consider both: the exploitation of the technological potential of the systems **and** they have to ensure the communicability to the wide range of users.

It seems encouraging to me, that the emerging wide-spread application in mass produced-goods have already started to adjust the the R&D activities in this direction. The awareness of ICT as a **tool**, that can not provide environmentally positive effects only by itself, is a good a starting point for an environmentally more consciuos and reflecting approach towards the goods and processes involved.

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