

Michael Stein · Peter Sandl Editors

# Information Ergonomics

A Theoretical Approach and  
Practical Experience in Transportation

 Springer

# Information Systems in Transportation

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## 1 Introduction

The increasing significance of information technology as well as application networks for varying areas, e.g. aviation and shipping as well as automobile and rail traffic are characteristic traits of an information society (cf. Harms and Luckhardt 2005). Further developments in the fields of microelectronics, computer, software and network technology, but also display technology, etc. are the driving force of this progression.

While the operator was provided with control relevant information via conventional instruments on the one hand and in the form of hardcopies on the other hand, i.e. in a more linear format (e.g. standard flight manual) prior to informatization, current technology enables the storage and presentation of this information<sup>1</sup> in a

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<sup>1</sup> Information is “(...) that subset of knowledge which is required by a certain person or group in a concrete situation to solve problems and which frequently is not available. (...) If it was to be expressed in a formula information is ‘knowledge in action’” (Kuhlen 1990, pp. 13 and 14). “This is in line with the psychological concept of information in the framework of ‘ecological perception’” (Gibson 1979); however, Gibson makes the further important distinction between the two modes “direct information pick-up” and “indirect information pick-up”, in the first mode data provide the information for action immediately, in the second case data have to be semantically processed in order to guide action. A typical example for direct information pick-up is landing a plane without instruments (Gibson, Olum & Rosenblatt 1955). In the following, the mode of indirect information pick-up will be predominant. However, e.g. the ‘intelligent’ preprocessing of the data and their display in 3-D can provide a kind of illusory direct information pick-up.” In the following the term used in relation to the term “information system” will always be “information”, knowing very well that initially “data” are stored in information systems and these data can only become “information” in interaction with the recipient.

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multi-media and hypermedia format. Therefore, the term "multimedia" is defined as follows: "a combination of hardware, software, and storage technologies incorporated to provide a multisensory information environment" (Galbreath 1992, p. 16). If texts, graphics, images, sounds, and videos are provided with cross-reference links, this application becomes a hypermedia application (cf. Luckhardt 2000, p. 1; cf. Issing and Klimsa 1997; Schulmeister 2002; Holzinger 2001; Gerdes 1997).

In addition to a "novel" presentation of information further progress can be observed in the field of transportation: the increasing extent of automation. The human machine interface is currently characterized by both, the changes in the presentation of information (also information access!) as well as a higher degree of automation. The changing processes in aviation can be quoted as examples, which are characterized by the introduction of integrated information displays (multi function displays, glass cockpit concept) as well as enhanced and synthetic vision systems (tunnel in the sky). The progress described can generally be observed with a certain time delay within the automobile sector and in other transport areas.

In addition to informatization the increase of available information results in the mediatization of the described areas. This means that control and action relevant information on system and environment conditions is made accessible to an increasing extent via sensor systems and subsequently presented in media (displays). One example in this regard is the enhanced and synthetic vision system. Via sensor data fusion this system generates an image of the environment surrounding the aircraft, which is augmented by relevant information (enhanced vision). This type of information presentation eventually eliminates the need for pilot external view. Such systems are significant in poor weather conditions in which the real external view yields no reliable information. The aim is an increased situational awareness of the operator, thus ensuring safe operation, while at the same time improving economy. Latter is crucial for transport companies, particularly in times of global trade and also global competition.

However, with regard to the described developments we have to note that the cognitive capacity of man represents the bottleneck with respect to information handling. At the same time, the cognitive resources employed with regard to immensely increasing technical possibilities and also information options for the availability and accessibility of information are nearly the same as prior to the beginning of the "media age" – in spite of improved "education and training". In this context it should be noted that in addition to content knowledge new media also require an increasingly complex strategic knowledge with respect to information retrieval. Furthermore, new media make high demands on communication skills, particularly the capability of differentiating between relevant and non-relevant information. We should also note that new media and the users' media competence are undergoing constant developments and are thus constantly changing. Hence, the user has to dedicate part of his cognitive resources to new learning processes.

In the context of this development the negative effects, e.g. the keyhole effect, tunnelling, fixation, and absorption, should be analysed very precisely in addition to the positive effects like the improvement of the human machine interface by means of a more effective presentation of information (and thus an increase in the safety and reliability of overall systems).

This brief outline encompasses the use of electronic flight bags as detailed in this paper which now provide checklists formerly on paper and other flight and organization relevant information to the pilot as hypermedia-based electronic documentation (information systems). The objective is to provide the pilot with more up-to-date and situation-specific information, improve user friendliness and information accessibility as well as to introduce a paperless cockpit for economic reasons (Anstey 2004).

Referring to these trends Stix (1991) describes the change from traditional cockpits with traditional dial-type instruments to the glass cockpit in his paper titled "Computer pilots. Trends in traffic technology". The role perception of the pilot as an "aviator" is examined critically in this paper. Within the scope of automation the pilot has turned into a system operator, monitoring and controlling the aircraft via multi-function displays and information systems and taking into account economical considerations regarding ideal velocity and altitude in relation to the current personnel costs by using information systems (Haak 2002). The presentation options in the cockpit and the partially resulting data flood in this context frequently cause excessive strain leading to user questions such as: "What's the system doing?" and "What mode is the system in?" (Haak 2002). This demonstrates the significance of an adequate ergonomic design of the presentation of information to improve safety and efficiency. In sum, developments will enable more sophisticated and complex information systems in aircraft, presenting much more than information on primary flight displays (PFD), navigation displays (ND) and system parameters (primary engine display, PED, etc.), as has already been implemented in part. The future belongs to networked, hypermedia-type information systems operated by pilots (system managers) in those work phases in which they are not linked to primary flight controls.

Ramu (2004a, p. 2) as one of the leading researchers of the European Institute of Cognitive Science and Engineering (EURISCO International) states the following in this context: "Once web technologies will enable large industry applications, the knowledge of the whole aeronautical community will be available in a dynamic and interactive way."

## 2 Definition: Information System

Due to the fact that information systems are applied in various fields (e.g. business data processing, management, library and information science, driver information systems, flight management systems) there is also a large number of specific, partly very pragmatic definitions as it is also the case in the field of transportation. It is, however, difficult to find general definitions and descriptions of the term "information system". Subsequently, we shall attempt to achieve a general definition and description of information systems and describe a driver information system on the one hand and electronic flight bag on the other hand as examples for information systems in the field of transportation.



Business data processing provides a general definition which is also adequate for the field of transportation: "An information system can be defined technically as a set of interrelated components that collect (or retrieve), process, store, and distribute information to support decision making, coordination and control in an organization" (Laudon and Laudon 2008, p. 6).

Kroenke (2008) states that an electronic information system consists of hardware, software, data, procedures, and people. From this perspective information systems are socio-technical systems with the aim of optimum provision of information and communication. These systems are divided into human and machine subsystems. On this basis, Krcmar (2003, p. 47) extends the definition as follows: "Information systems denote systems of coordinated elements of a personal, organizational and technical nature serving to cover information needs."

With regard to hardware, input units (e.g. keyboard, mouse, touch screen) and output units (e.g. computer screen, multi-function displays) can be distinguished. With respect to information systems, Teuber (1999) makes a distinction between application systems (technical components) and the user. The application system consists of hardware and software, with software being divided into basic software and application software.

Apart from the described definitions with the focus of reference on socio-technical aspects Kunz and Rittel (1972) tend to emphasize contextual aspects. With regard to the characterization of the term information system (under the aspect of information system characteristics) the authors focus on the capability of a user to solve a problem within a specific problem context using information systems. "Information systems are provisions which should enable and support external "information" of a user (or a category of users) with regard to a category of his/their problems" (Kunz and Rittel 1972, p. 42).

The following major tasks can be derived from the described definition with respect to designing an information system: a "user analysis" (or classification of users or their characteristics and preferences) as well as an "analysis of problem categories/situations" and their relation (cf. Kubicek et al. 1997).

On this basis Kuhlen (1990, pp. 13–14) states: "Information systems shall provide information to persons in specific problem situations. In this way information systems expand the quantity of knowledge available to human minds. Information is not gained from within oneself or by introspection, information is not remembered. Information is sought from external sources".

An exact description of the problem context, the awareness of the original and target state as well as the operators required for transformation, are of relevance for problem solutions. This is crucial particularly for examining the information gained with regard to its relevance; it is possible that information has to be transferred to the problem situation and stored cognitively until a problem has been solved.

Furthermore, Kunz and Rittel (1972, p. 43) limit the aforementioned definition by declaring the general process of generating information and the provision of information as non-relevant, while qualifying the relation between the generation/provision of information and the support for problem solutions as highly relevant. "A system qualifies as an information system because it should contribute to

information and not because it generates or contains information. Only data, which can result in information for the user in a given problematic situation are stored or generated. An information system only includes data which will contribute to external information, i.e. which is not realized as internally generated (e.g. ideas, rethinking processes, etc.). This does not preclude the fact that information systems may not cause internal processes of knowledge diversification (by means of external stimuli)".

In summary, indicating the limits of information systems, Kunz and Rittel (1972, p. 42) state: "the goal of the design of information systems ultimately is to make provisions for a category of problematic situations an actor or a category of actors expect to encounter. Information systems are therefore always set up for categories of problematic situations and frequently for categories of actors." Contrary to this ideal perspective every problematic situation can be seen as unique. To this end, no information system has the capability to provide the total information to solve a problem.

### **3 Criteria for the Assessment of Information Systems: Data and Information Quality**

Data and information quality are crucial to the quality of an information system, regardless of its application range. The terms data quality and information quality are frequently used as synonyms in publications in the field of business data processing. In this context data quality covers technical quality (e.g. hardware, network), while information quality (information access) covers non-technical aspects (Madnick et al. 2009,<sup>2</sup> see also Helfert et al. 2009). Furthermore, Wang et al. (1995) criticize the fact that there are no consistent definitions of the terms "data quality" and "information quality" in scientific research. Price and Shanks (2005) as well as Mettler et al. (2008) put this down to the fact that there are four different scientific approaches with regard to the definition of data quality and information quality: "empirical, practical, theoretical and literature based" (Mettler et al. 2008, p. 1884).

In an article giving an overview of database (information) quality Hoxmeier (1997a, b) states that numerous approaches have been developed over time in the attempt to set up "factors, attributes, rules or guidelines" for the evaluation of information quality (Martin 1976; Zmud 1978). In this context the authors established a number of evaluation dimensions. Various studies (Helfert et al. 2009, p. 1) also show that information quality is a multidimensional concept. So far, the scientific community has not agreed on a consistent definition.

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<sup>2</sup>With regard to the publication by Madnick et al. (2009) no distinction will be made between technical and non-technical aspects within the scope of this publication.



One of the early approaches of evaluating computer based information systems and information quality was established by Martin (1976). He proposes the following 12 evaluation criteria:

- “Accurate,
- Tailored to the needs of the user,
- Relevant,
- Timely,
- Immediately understandable,
- Recognizable,
- Attractively presented,
- Brief,
- Up-to-date,
- Trustworthy,
- Complete,
- Easily accessible”.

With regard to information quality (IQ) Wang and Strong (1996, cf. Strong et al. 1997) differentiate between the following:

- “Intrinsic information quality: Accuracy, Objectivity, Believability, Reputation
- Contextual information quality: Relevancy, Value-Added, Timeliness, Completeness, Amount of information
- Representational information quality: Interpretability, Ease of understanding, Concise representation, Consistent representation
- Accessibility information quality: Accessibility, Access security”.

Based on the research by Wang and Strong (1996) the “Deutsche Gesellschaft für Informations- und Datenqualität” (German Society for Information and Data Quality<sup>3</sup>) has derived the following criteria:

- “Accessibility (information is accessible if it is directly available to the user by applying simple methods),
- Appropriate amount of data (the amount of data is appropriate if the quantity of available information fulfills the requirements),
- Believability (information is considered believable if certificates prove a high standard of quality or considerable effort is directed to the acquisition and dissemination of information),
- Completeness (information is complete if not missing and available at the defined times during the respective process steps),
- Concise representation (information is concise if the required information is presented in an adequate and easily understandable format),

<sup>3</sup> Committee: “Normen und Standards der Deutschen Gesellschaft für Informationsqualität” (Standards of the German Society for Information Quality, [http://www.dgiq.de/\\_data/pdf/IQ-Definition/IQDefinitionen.pdf](http://www.dgiq.de/_data/pdf/IQ-Definition/IQDefinitionen.pdf). Accessed 28th January 2010).

- Consistent representation (information is presented consistently if displayed continuously in the same manner),
- Ease of manipulation (information is easy to process if it can be modified easily and used for various purposes),
- Free of error (if information is conform with reality),
- Interpretability (interpretation of information is unambiguous and clear if understood to have identical, technically correct meaning),
- Objectivity (information is considered objective if it is purely factual and neutral),
- Relevancy (information is relevant if it provides necessary information to the user),
- Reputation (information is valued highly if the source of information, transport media and the processing system have a high reputation of reliability and competence),
- Timeliness (information is considered current and up to date if the actual characteristics of the described object are displayed in near real time),
- Understandability (information is understandable if directly understood by the users and employable for their purposes),
- Value-added (information is considered to be value-added information if its use can result in a quantifiable increase of a monetary target function)".

Since this list refers to business data processing we have to assess very carefully which criteria are relevant to the field of transportation.

In the context of transportation the objective of information systems (information) is the support of the operator in specific problem categories within the scope of system control to contribute to finding a solution. Since a successful solution depends on

- The operator (knowledge, training – novice, experienced, expert, etc.),
- The information system (receivability of information, design of information, adaptivity),
- The system status (e.g. complexity of the failure) as well as
- The environmental conditions (complexity),

the neutral information content can be determined only empirically for certain operator populations as well as problem and situation categories (cf. Information Science). In this context quality and significance of information depend on their access and contribution to the problem solution. This can be simulated for instance under experimental conditions in the flight simulator. Abnormal situations, for example, can be simulated in certain flight phases during which the support of adaptive warning panels or electronic flight bags is used as a problem solution.

When considering the phases of information access (see Stein 2008) and the implementation of information under the aspect of system control (or also system monitoring) the subjectively perceived quality of information depends on the objectives, expectations, capabilities (operation of the information system), specialist knowledge and the field of application (e.g. system knowledge with regard to



the aircraft, scope and quality of the problem, etc.) and the perceived characteristics of information and information system (user-friendly design, concise, conform to expectations). There are the following expectations of information characteristics:

- Duration of information search,
- Scope of information,
- Context sensitivity of information (information system adapted to the dynamic system and environmental conditions),
- Time of availability of information,
- Presentation of information,
- Cost benefit of information,
- Interreferential information.

The terms “recall” and “precision” can be used to determine the quality of information systems. The first index includes the ratio between the relevant documents found within an information system and the total number of documents. The second index describes the number of documents found which are at all relevant. The values for recall and precision range between 0 and 1. The closer the index is to 1 the more relevant documents were found Luckhard (2005).

## 4 Context of Use Regarding Information Systems

### 4.1 *Electronic Flight Bag*

More and more airlines replace traditional paper-based documentation (e.g. emergency checklists, Instrumental Flight Rules, aircraft and flight operations manuals) by electronic documentation presented and stored in so-called electronic flight bags. Examples in this context are Lufthansa and LTU (Skybook), Austrian Airlines (Project Paperless Wings) as well as GB Airways (Teledyne Electronic Flight Bags). The objective is a paperless cockpit with all related economic savings (less update effort, etc.), possibly improved user friendliness and information accessibility (Anstey 2004). The use of electronic flight bags shall provide the pilot with more up to date and situation adequate information, which should also contribute to enhance flight safety. In this respect Ramu (2004a, p. 1) postulates the following: “The final role of operational documentation is to help the end user to access the right information at the right time, in the right language, and the right media at the right level of detail using the right device and user interface”.

Chandra et al. (2004) mention the low costs compared to traditional avionics applications on the one hand and the vast range of functionalities and their flexibility and thus also their application in various different flight sectors, e.g. charter/business, air transport or regular airline transport on the other as reasons for the rapid development and increased use of electronic flight bags. These have the

potential for savings in this sector, which is characterized by intense competition, thus possibly resulting in a competitive edge.

In the field of military aviation checklists are also partly stored electronically and made available to pilots in this way. Based on operational conditions, especially of combat aircraft (G forces, bearing) in military missions Fitzsimmons (2002), however, states that portable equipment, e.g. handhelds as used in civilian aviation, is suitable only to a limited extent for military missions. This type of equipment poses a threat to safety, e.g. during emergency egress or also due to possible sun reflections.

#### **4.1.1 Definition and Classification of Electronic Flight Bags**

For the field of civil aviation the term electronic flight bag is defined in the Advisory Circular of the Federal Aviation Administration (FAA AC 120-76A 2003, p. 2) as follows: "An electronic display system intended primarily for cockpit/flight deck or cabin use. EFB devices can display a variety of aviation data or perform basic calculations (e.g., performance data, fuel calculations, etc.)". The following description is also included: "(...) In the past, some of these functions were traditionally accomplished using paper references or were based on data provided to the flight crew by an airline's "flight dispatch" function. The scope of the EFB system functionality may also include various other hosted databases and applications. Physical EFB displays may use various technologies, formats, and forms of communication. These devices are sometimes referred to as auxiliary performance computers (APC) or laptop auxiliary performance computers (LAPC)".

The US Air Force Materiel Command which is concerned with the transformation of paper-based technical orders (TOs for the technical maintenance of aircraft) and also the conversion of checklists (Flight Manuals Transformation Program [FMTP]) into electronic documents also defines electronic flight bags as follows: "A hardware device containing data, previously available in paper format (flight manuals, electronic checklists (ECL), Flight Information Publication (FLIP), Specific Information (SPINS), AF Instructions, TPC charts/maps, etc.), required to operate and employ weapon systems. A more realistic role of the EFB is supporting information management. Information management attempts to support flexible information access and presentation so that users are enabled to more easily access the specific information they need at any point in the flight and to support effective, efficient decision making thus enhancing situational awareness" (Headquarters Air Force Materiel Command, Flight Manuals Transformation Program Concept of Operations 2002, p. 15).

In particular, this extended definition highlights the options of managing and employing force systems more adequately using electronic flight bags. The definition also refers to information management, which provides the pilot with up to date information during each flight phase. Furthermore, the use of electronic flight bags



should make decision-making processes more efficient and effective, thus supporting situational awareness of the pilot.

The Advisory Circular of the Federal Aviation Administration (2003) differentiates between three hardware and three software categories of electronic flight bags:

- Hardware category 1 includes commercial off-the-shelf, portable personal computers, which are not permanently installed in or connected to other aircraft system units. There are no mandatory certification processes for this type of equipment. Products of this category shall not be used in critical situations.
- Hardware category 2 is also characterized by commercial off-the-shelf transportable PCs, however, these are connected to specific functional units in the aircraft during normal operations. Certification processes are mandatory for this category.
- The third hardware category comprises permanently installed electronic flight bags (multi-functional displays). These are subject to certification processes.
- Software category A consists of flight operations manuals and company standard operating procedures. An approval by the Flight Standard District Office is necessary for this category.
- Software category B includes more effective programs, which can be used for calculations, etc. (weight and balance calculations, runway limiting performance calculations). An approval by the Flight Standard District Office is necessary for these programs.
- Software category C comprises programs subject to certification, which are used for determining and displaying the one's own position in maps which are coupled to other systems (own ship position). However, these must not be used for navigation.

Due to the fact that electronic flight bags represent a rather new accomplishment their practical use in the coming years will decide which of the categories described will best cover the requirements of various aircraft applications (general and military aviation) and which will be successful on the market.

#### 4.1.2 Composition and Structuring of Electronic Flight Bags

In the course of the development of electronic flight bags the available paper based documentation was initially converted on a "one-to-one basis" into electronic documentation (Barnard et al. 2004). In this respect Ramu (2002) states that typical characteristics of paper-based documentation, e.g. outlines in chapters or linear coherence generated by subsequent pages, will be lost in electronic documentation. New forms of presentation ("characteristics") should be defined.

Questions in this context are for example the following:

- How to design information hierarchy and access (cf. system approach or task approach, Ramu 2002),
- The coexistence between paper based and electronic documentation,

- Prioritization to support the simultaneous management of various databases/documents,
- Navigation to required information,
- And the security of e-documents.

Hence, one of the most important questions with regard to the development of electronic flight bags is the “ideal method” of transformation of traditional paper-based documentation – for flight operations as well as maintenance – to electronic documentation. Anstey (2004), an expert in electronic documentation applications at Boeing AG, proposes an initial analysis of available paper based documentation with respect to its composition and structuring (chapters, structured vs. non-structured), format (Word, pdf-file, etc.) and the contents presented. The following are subsequent questions:

- “Does it make sense to adopt the given structure of the paper-based version in electronic documentation?”
- “Is the organization of the documentation adequate for display presentation?”
- “How many information levels should the electronic documentation have?”
- “Can tables, diagrams and graphics be integrated adequately – and in particular readably – in the electronic documentation?”

Furthermore, Anstey (2004) postulates that it is essential to take into account the know-how of the end users (pilot) and their experience and capabilities for an adequate design of electronic flight bags. The following are relevant from an ergonomic point of view:

- Experience and knowledge of the various flight decks,
- Frequency of use of various manuals,
- Identification of flight phases during which specific manuals are used,
- Organization, structure and composition of electronic flight bags,
- User access to contents,
- Navigation instruments within electronic flight bags for information retrieval,
- Links,
- Integration in flight deck data,
- Presentation of tables and graphics,
- Identification of non-relevant information.

Barnard et al. (2004) postulate that the presentation of documentation (paper-based vs. electronic) will not only change, but it rather will become less important for flight operations. They list the following reasons:

- Required data (information) is integrated in existing systems (displays),
- More independent (self-evident) systems,
- Improved links to ground stations and thus also improved support,
- Increasing complexity and automation of systems (resulting in the fact that the capabilities of the users as well as the requirement to understand the systems by reading documentation during flight will decrease),



- “(…) ubiquitous computing, making available any information anywhere and just-in-time, not necessarily contained in a specific device in a specific form” (Barnard et al. 2004, p. 14).

Some of the arguments, e.g. the “integration of additional information in existing subsystems” (multi-function displays) seem plausible, however, fundamental considerations concerning the design of information systems (structure and organization) in accordance with human factors criteria will still be necessary. Other arguments, e.g. the “ubiquitous availability of information” have already proven false in other highly computerized sectors since it is not the availability of information which is crucial to its usability, but rather the extent of information which can be processed cognitively by the user.

The use of documentations will also be undergoing changes. In this context, Barnard et al. (2004) differentiate between use during flight and use during training. During the flight phase information is required for the selection of tasks (decision making), anticipation of tasks and their effects, sequencing of tasks as well as performance of tasks. Further fields of use include preparation and debriefing phases comprising e.g. simulations or representing specific weather conditions or also flight scenarios/manoeuvres. In the field of training electronic documentation is used as a source of declarative knowledge as well as for computer-based training or also as a dynamic scenario generator.

Ramu (2002) established one method for the user-oriented structuring of electronic documentations, which was also discussed and implemented within the scope of the A 380 development. As demonstrated by the example of Flight Crew Operating Manuals (FCOM) the basic idea is to relate the structuring of electronic documentations to the sequence of tasks to be performed during flight. Task-based documentation takes into account the fact that the work (tasks and subtasks) of a flight crew during flight is time-critical and limited within a specific timeline. Since the cognitive structure of the end user (pilot) is conform also to this timeline and the sequential task requirements it makes also sense for the structure of electronic documentation to be oriented to this critical timeline. This means that the respective relevant information is attributed to the successive tasks for the purpose of “user friendly” information retrieval.

The structuring process is based on the concept of the Documentary Units (DU), which includes the segmentation of all available data in so-called entities. A documentary unit contains data, e.g. descriptions, schematics, animations or also performance data, etc. on the one hand and documentary objects associated with style sheet metadata properties, e.g. colour, type size, spacing, etc. on the other (cf. Ramu 2004a, b). Documentary units are hierarchically organized in sub-documentary units. These are classified in specific user-oriented domains. For the Flight Crew Operating Manual (FCOM) these are subdivided into the following user-oriented domains: Procedures, descriptions, limitations, performances, supplementary techniques, and dispatch requirements. For the optimization of the information retrieval process so-called descriptors – metadata – are assigned to each documentary unit; these are domain descriptors, context descriptors, task

descriptors, etc. Their task is to describe the respective contents of the (self-sufficient) documentary units and their contexts.

Ramu differentiates between three categories of descriptors in aviation:

- The artefact family (system [e.g. hydraulics] and interface [e.g. overhead panel]),
- The task family (phases of flight [takeoff, cruise, landing] and operation [e.g. precision approach]),
- The environment family (external and internal environment).

The task-oriented structuring of electronic documentations is based on the task block concept. Ramu (2002) describes the concept as follows: "A task can be represented as a Task-Block, taking into account its context history through Task Descriptors (TD), and leading to a set of actions (Ramu 2002, p. 2)".

Ramu proceeds to introduce the concept of task block organization consisting of several data layers. He uses the image of a house as an analogy. The house symbolizes the highest layer, e.g. flying a specific aircraft type from one location to another (house task descriptor). The second layer of task descriptors includes the successive flight phases of preparation, departure, cruise and arrival. The individual flight phases can be considered to be rooms. There are so-called Standard Operation Procedures (SOP) for each one of these rooms.

In his later work (Ramu 2004a, b, p. 3) he introduces the meta-concept of ontology for classification (see Fig. 1), referring to a definition by van Heijst (1995). "An ontology is an explicit knowledge-level specification of a conceptualisation, e.g. the set of distinctions that are meaningful to an agent. The conceptualisation – and therefore the ontology – may be affected by the particular domain and the particular task it is intended for".

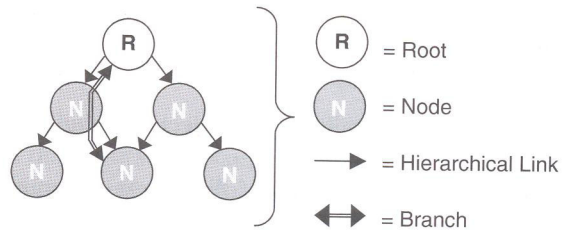
With regard to the structure and composition of ontologies Ramu (2004a, b) further explains: "An ontology dimension will take the form of a logical tree, with one root, multiple nodes hierarchically organised through multiple branches. Root and nodes are context descriptors".

The aforementioned task family and environment family are linked in various ways. This fact is illustrated by the example of poor visibility (environment family) affecting the landing and approach flight phases (task family). The operation category is subdivided into *n* operations to enable the performance of the tasks required in each flight phase. In this context each descriptor of an operation category is linked to an action to be conducted. The first ontology dimension is defined as the standard, representing all standard actions. If, for instance, the ontology dimension environment family changes the task family including its related actions are also affected. The individual ontology dimensions are independent of each other, meaning that the accounts A and B, for instance, are not connected (Fig. 2).

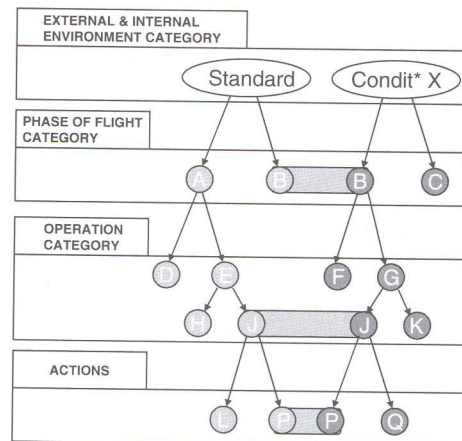
The briefly described approach to information structuring and information retrieval in electronic flight bags (the connection of a documentation to the sequence of tasks to be performed during a flight as well as the context sensitivity generated, etc.) can be described as an important step towards a user-oriented



**Fig. 1** Ontology dimension properties (Ramu 2004a, b)



**Fig. 2** Task and environment family ontology (Ramu 2004a, b)



design of electronic flight bags. However, future information will not only be presented “rigidly”, i.e. automatically, in accordance with specific flight phases using electronic flight bags, but the physical or psychological conditions of pilots (e.g. cognitive state) will also be taken into account with regard to the automatic selection of information. In addition, with the continuous improvement of sensor systems, “external factors” (the environment) will play an increasing role in the automatic presentation of information.

Next to information preselection, information access via searches and browsing is still relevant. We can also assume that there is a trend towards hypermedia structuring of information with regard to the presentation of information and thus similar design guidelines will apply as for other hypermedia information systems.

#### 4.1.3 Checklist for the Assessment of Human Factors

##### Characteristics of Electronic Flight Bags

With regard to the assessment of electronic flight bags the Advisory Circular of the Federal Aviation Administration (2003) explicitly indicated the requirement to assess electronic flight bags under the human factors aspect. However, no assessment procedure was specified (Chandra et al. 2004). A list of the most relevant

human factors topics, e.g. interface design, readability, fault tolerance and workload, etc. has been published as a guide. Based on previous recommendations and studies (Chandra and Mangold 2000; Chandra 2003, etc.) Chandra (2003) developed an evaluation tool for electronic flight bags. The target group of this tool consists of FAA evaluators on the one hand and system designers on the other, who can assess the conformity of the designed systems with regulations using the tool during the development process prior to the actual FAA evaluation. The addressees are explicitly non-human factors experts. Chandra et al. (2004) developed two checklists: one checklist on a meta level including 20 items and one specific checklist with 180 items, with the authors preferring the shorter version for test economical reasons: "We quickly realized that a short paper-based tool that could serve as a "guide for usability assessment" would be more practical" (Chandra et al. 2004). Contents of the short version include symbols/graphic icons (readability, understandability of designation, etc.), formatting/layout (type, font size, etc.), interaction (feedback, intuitive operation), error handling and prevention (error messages, error correction, etc.), multiple applications (recognition of own position within the system, changes between applications), automation (user control over automation, predictability of system reaction), general contents (visual, auditive, tactile characteristics of the system, color application, consistency) workload (problem areas), etc.

Within the scope of tool development several evaluations were performed, e.g. regarding understandability or also coherence of the items. To this end, teams of two evaluators each with different backgrounds – human factor experts, system designers, licensed pilots – assessed real systems and expressed their thoughts by means of the think-aloud method. The reason that the authors cite for this procedure is that a team of two evaluators will usually detect more tool errors than two people processing the system with the tool one after the other. Since the subjects were not part of the future target group they were handed out the basic document of the Advisory Circular of the Federal Aviation Administration (AC 120-76A) to get a feeling for the target group.

The procedure of the evaluation was as follows:

- Introduction (15 min),
- Task-based exploration (90 min),
- Instrument processing (short and long version, 60 min each) and
- Feedback (15 min).

The comments of the evaluators were assessed separately for the task-based exploration and the tool-based review; the data, however, could not always be assessed separately. The comments were then additionally categorized into three priorities and evaluated with regard to frequency. The tool was then modified in accordance with the results of the evaluation. Items with only minor reference to the human factor aspect were sorted out or reformulated if not understandable. Furthermore, in view of the fact that system designers make specific requirements for the evaluation tool, e.g. support of the workflow, design changes were made.

All in all, the tool for the evaluation of electronic flight bags (Chandra et al. 2003) can be used as a screening instrument in a time- and cost-saving manner to



indicate “major” human factors errors. As noted by Chandra (2003) the tool cannot replace regular human factors and usability tests. The downsides are that errors can indeed be identified using the tool, however, no solutions or approaches are provided.

## 4.2 *Driver Information System*

In contrast to air, rail, or sea traffic, road traffic is characterized by a comparable lack of specific rules and very few standard procedures – plus a nearly complete lack of any kind of centralized oversight and control. That is, the amount of possible situations and the resulting demands on decisions and behaviour of drivers exceeds the possibility of regulations for any specific situation.

For this reason, the German law regulating traffic behaviour (StVO) starts with a very general statement concerning the obligations which all traffic participants must meet (§1): In all situation the behaviour has to be such that no other participant is endangered or unduly impeded. Similar general (“catch all”) formulations can be found in the laws regarding traffic behaviour of most countries. The necessity for such a general obligation of due diligence in traffic behaviour can be seen in its importance for most traffic related litigations.

The consequence of this regulatory situation in road traffic is that the responsibility of the individual driver is of utmost importance – and not that of centralized institutions as in air traffic control. For this reason, information systems for road traffic have to satisfy the needs of the driver in specific situations (in the following, only the term driver is used because information systems for other traffic participants still are in early stages of development and distribution). Of utmost importance, however, is that the interaction with these information systems does not only not interfere with the main task “driving”, but that the quality of the main task is improved by the information system (Dahmen-Zimmer et al. 1999). This is the core of the assistive technology approach to road traffic (Wierwille 1993).

In contrast to the guidelines for information systems cited in the first part of this chapter, information systems for road traffic are quite often

- Not integrated, segmental or insular
- Incomplete
- Not up to date and
- Inaccurate or incomplete.

This situation is due to the high complexity of road traffic with many independent agents, extremely variable situations, and extremely short response times. A general framework for such settings has been suggested by Suchman (1987); the concept of ‘situated action’ systematizes the interrelations between plans, situational constraints and opportunities (Dahmen-Zimmer & Zimmer 1997), and available resources.

Thus, the very nature of road traffic prohibits the development of general information systems which follow the cited guidelines for good information systems, instead, it necessitates supportive and assistive information systems which enable the driver to behave responsibly, that is, to minimize danger (and improve safety) and to contribute to a more effective traffic flow.

The driving task requires a whole range of modes of behaviour, which can be classified on three levels: Regulating (e.g. lane keeping), manoeuvring (e.g. overtaking), and navigating (e.g. goal setting; Verwey & Janssen 1988).

The time available for information processing in traffic is usually very short, typically

- 250–400 ms for regulation (e.g. lane keeping, keeping the necessary distance to other traffic participants, or adjusting the speed according to a traffic sign)
- 1,000–3,000 ms for manoeuvring (e.g. doing a left turn, switching the lane, or overtaking)
- 10,000 ms and above for navigating (e.g. choosing the right roads for attaining a set destination, taking a deviation in case of traffic congestion, or searching for service).

For the support of regulating behaviour, information systems have to be extremely fast, rely on incomplete or fuzzy data, and therefore their output for the driver has to be in a modality compatible with the motor behaviour (optimally tactile) and in a way which is advisory for the driver and not compulsory (see Zimmer 2001). There exist assistive systems for lane keeping, distance warning, and traffic sign recognition – all with more or less detailed information systems in the background. However, the question concerning the best mode of feedback is still open. The general consensus is that the modality ought to be tactile in order to support the motor behaviour optimally but the optimal mode for giving information about speeding or deviating from the lane (e.g. force feedback in the steering wheel or the accelerator, vibrations, etc.) has still to be found, even conventions are missing (Zimmer 1998; Bengler 2001; Bubb 2001; Grunwald and Krause 2001).

The intelligent support for manoeuvring is most challenging because highly dynamic scenes with many independent agents have to be analyzed and evaluated in a very short time (Rumar 1990). In order to develop efficient assistive information systems for this level of driving, reliable car-to-car communication would be necessary, informing not only about the exact position, but also speed, and destination of any car in the environment in order to compute possible collision courses or to advise for an optimal traffic flow. The existing collision warning or prevention systems are therefore confined to scenes of low complexity, that is, with few agents, and low dynamics, that is, they are most efficient with static obstacles.

Only for navigating there exist information systems in the form of digitized maps, which come close to the above mentioned guidelines for information systems. In combination with wireless digital traffic information these systems provide good support for the optimization of way finding. The major short comings of the digital maps underlying the navigation systems are due to the fact that they do not implement recent and actual data regarding road construction or maintenance



and the information about traffic signs and regulations is updated only annually. These shortcomings are well known and have been addressed in research programs and guidelines of the EU but as long as the communal, state, and Europe wide data bases for the actual state of the road systems are not compatible a host of reliable and important data cannot be implemented into the navigation systems.

A further drawback for the users of these navigation systems lies in the fact that actual driving data are not collected and used for making the system more up to date. That is, information leading to inconvenient or even false suggestions for routes cannot be corrected because it is not possible for the driver to give feedback about obvious failures to the system. And the system itself does not register the fact that, for instance, a driver repeatedly and systematically deviates from the suggested routes.

In the beginning of this section, the lack of centralized oversight or control in road traffic has been mentioned. However, one exception for this should be noted: in the field of logistics there exist GPS-based systems of fleet control which allow not only just-in-time delivery but also improve the efficiency of the fleet. However, these systems are usually confined to single providers for supply chain management. The competitive edge for any logistics provider is to be better than the others; therefore exchange of information between corporations is scarce. Thus, the existing information does not improve the overall efficiency of the road traffic system.

## 5 Further Developments

In order to chart the further development of user oriented information systems for road traffic it is necessary give a systematic overview of the user's demands: **what** is needed **when** and **how** to be known by the user, that is, beyond what is obvious or already known by the user. Future systems have to address the following main topics: situational and individual specificity of information, actuality and relevance of the information, and effectivity of the mode of transmitting this information to the user.

Due to the described complexity of events in road traffic, centralized information systems beyond the existing digital maps will not be possible. The focus will be directed on information systems supporting the individual driver in very specific situations. Such systems ought to be local, in the extreme case covering only the traffic in a certain junction. If it is possible for the area of interest to localize all traffic participants, to determine their velocity and direction, and to project the most probable trajectories, an optimal traffic flow can be computed and corresponding information for the guidance of individual drivers can be provided.

However, the effectivity of such a local traffic management system will depend on the willingness of the drivers to comply with the suggestions given by this system. Partially this compliance can be enforced, e.g. by traffic lights and adaptive traffic regulations, but – at least for the foreseeable future – it will not be legally possible to directly influence acceleration and deceleration of the cars in this

situation. This has to be done by communicating suggestions to the drivers how to manoeuvre their cars. The quality of such a local system would be enhanced if all cars are equipped with car-to-car and car-to-system communication. For the near future this will not be the case and therefore the necessary information has to be determined by high-speed video observation and analysis. The communication about the effective traffic flow via the traffic management system has to be very fast because any delay of relevant messages will influence the trust into this system and therefore diminish the willingness to comply with the guidance information.

In order to provide not only local support and a local improvement of traffic flow but also an overall improvement, the local information systems have to be designed in such a way that they can interact with other local information systems and higher level traffic management systems in order to prevent traffic congestions on a larger scale. This kind of regional guidance information is already provided by digital traffic information messages, which interact with in-car navigation systems. However, the lack of actuality and reliability of such information blocks compliance in most cases.

From our point of view, the future of information systems for traffic will lie in the development of situation specific but interconnected systems, providing information that fits the actual demands of the driver. In order to achieve this goal, further investigations of time structure and interaction patterns of traffic will be necessary for a better match between what the driver observes in a specific situation and what information is provided for a better and safer traffic flow. As long as enforced compliance is neither technically feasible, nor legally admissible, traffic information systems have to enhance and assist the competence of the driver and not to govern or override it.

The effective mesh of driver competence and information support will depend on the quality of the information given, its specificity for the situational demands, and the fit of the mode of informing and the resulting actions.

The challenge for information science will be the communication between the systems on the different levels, from the systems providing information for the lane keeping of a single car, to the regional or even more general traffic management. If this effective communication between systems can be achieved, it will be possible to reach more safety (see the "Vision Zero": "the goal for road traffic safety proposed by the commission of the European Union") and effectivity.

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