

Maila Herrala

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ISBN 978-951-38-6938-0 (soft back ed.)

ISSN 1235-0605 (soft back ed.)

ISBN 978-951-38-6939-7 (URL: <http://www.vtt.fi/publications/index.jsp>)

ISSN 1455-0865 (URL: <http://www.vtt.fi/publications/index.jsp>)

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JULKAISIJA – UTGIVARE – PUBLISHER

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Technical editing Anni Kääriäinen

Editia Prima Oy, Helsinki 2007

Herrala, Maila. The value of transport information. Espoo 2007. VTT Tiedotteita – Research Notes 2394. 87 p. + app. 5 p.

**Keywords** transport information services, transport telematics, quality assessment, value assessment, value of information, logistics services, information attributes, travel information services, value chains, valuation methods

## **Abstract**

Information value has been mostly discussed in business and information economics. Now, due to the fast development of communication technologies, a new interesting field of research has emerged – transport telematics. The objectives of this research were to identify the attributes affecting the value of transport information, and to specify the valuation methods applied. This study also includes discussion on three case studies concerning transport telematics. A further objective was to identify the relevant information attributes and the feasible assessment methods for each case. The study was carried out at VTT Technical Research Centre of Finland with co-funding from Tekes – the Finnish Funding Agency for Technology and Innovation.

The first part of the study, a literature survey resulted in a general framework for information value assessment. This framework can be used when evaluating various transport information to analyse which information characteristics need to be taken into account, and which assessment methods should be applied. This framework can be presented in two tables, where the first one identifies the information quality attributes, and the second one attaches these to the appropriate value assessment methods in each case. The second part of the study deepens the first part by applying the general framework to real-life information by studying three transport information service cases on the basis of available data. In each case, the relevant information value characteristics are identified and the appropriate assessment methods specified. The case studies proved that the evaluation framework was useful for evaluating information value.

The evaluation framework was created from the perspective of transport information. Hence, it is most suitable for evaluating the value of information provided by the transport service sector. In addition to the theoretical valuation of information, this framework can, however, be used as a basis for deeper and more detailed investigation, and also in research more empirical than the cases studied here. It is also likely, that the framework could be applied to other kinds of information, but in this case the valuator needs to carefully adapt the framework to suit the type of information in question.

## **Preface**

This work is part of a wider project concerned with creating a holistic evaluation framework for information services. The research has been mainly conducted at VTT Technical Research Centre of Finland. The project was started in 2003 and it will be continued further. Other main financiers of the project are Tekes – the Finnish Funding Agency for Technology and Innovation, the Finnish Meteorological Institute, Destia and Ministry of Transport and Communications Finland. The topic of this research is the value and valuation of information, this problem has preoccupied researchers on many occasions. The object of this study is to find a solution to this problem by finding out what factors contribute information value and how these factors can be assessed. This work was originally conducted as a Master's thesis project on the initiative of Pekka Leviäkangas. The manuscript was commented several times by Harri Haapasalo from University of Oulu, and Pekka Leviäkangas, Risto Kulmala, Raine Hautala and Pirkko Rämä from VTT. I thank you all for your support and encouragement.

Oulu, 25.5.2007

Maila Herrala

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## List of abbreviations

3PL	Third-Party Logistics provider
AHP	Analytic Hierarchy Process
ATIS	Advanced Traveler Information Service
ATMS	Automatic Traffic Monitoring Station
B2B	Business-to-business marketing
B2C	Business-to-customers marketing
CLM	Car Location Message
ETA	Estimated Time of Arrival
EVPI	Expected Value of Perfect information
EVSI	Expected Value of Sample information
FCD	Floating Car Data
FTP	File Transfer Protocol
HTML	<i>Hypertext Markup Language</i>
ISP	Information Service Provider
ITS	Intelligent Transportation System
PDA	Personal Digital Assistant
<i>pdf</i>	probability density function
PIV	Perceived information value
RDS-TMC	Radio Data System-Traffic Message Channel
RTI	Road Transport Informatics
RTTI	Real-Time Traffic Information
TIS	Traveller Information Services
VTTS	Value of Travel Time Savings
WML	<i>Wireless Markup Language</i>
WTP	Willingness To Pay
XML	<i>eXtensible Markup Language</i>

## List of symbols

$A=\{a\}$	action space
$a_0$	optimal prior action
$a_y$	optimal action, conditional on message $y$
$C$	cost of accessing, cognitive processing and applying the message $y$
$C(\bullet)$	cost function
$E$	expectations operator
$E(y)$	expectation value of $y$
$E_{x y}$	denotes expectation with respect to $p(x y)$
$E_x \pi(x, a_0)$	expected payoff without the source
$G$	realized incremental gain from incorporating information into the decision problem
$I$	available information
$p(x y)$	the posterior probability distribution of the state, conditional on the message
$\pi(x, a)$	payoff function
$V(\bullet)$	information value function
$X=\{x\}$	state space
$x$	state that occurs after the choice
$Y=\{y\}$	message space
$y$	message
$u$	utility function for terminal wealth
$w$	initial wealth
$W$	terminal wealth
$W$	set of potential terminal wealths
$\omega$	outcome function

# 1. Introduction

## 1.1 Research background

Along with the fast development of communication technologies a lot of new potential for information services has emerged. Transport information services, including travel, traffic and logistic services, is one of the most rapidly developing areas of information services and their markets may prove to be even larger than estimated. Especially, in large metropolitan areas traffic volumes are increasing rapidly with negative consequences for traffic fluency and safety. This development has increased road users' interest towards information services which provide solutions to travel problems. (Laakso et al. 2006.) Several different services that provide information about congestion, travel times and for example alternative routes are already available to customers around the world. In Finland, traffic telematics markets are at a developmental stage and at the moment they mainly concentrate on a few public sector actors in big cities. (Mäkinen et al. 2005.)

It is often easy to attach a certain value to a physical product, but how can one evaluate information? Information differs from physical goods in that its dimensions and quantity are usually hard to measure, and its value greatly depends on the valuator and the usage of the information (Lawrence 1999, Taylor 1986). This being the case, how do information attributes and the valuator's characteristics affect information value? Traffic conditions, time, information quality, and the user's characteristics affect the overall value of information and the benefits user can get by using the information (see f. ex. Ahituv 1989, Khattak et al. 2003, Jiang & Morikawa 2004).

The range of information services has become wider and wider as more versatile, and precise real-time customized travel information services become available. However, the following questions have been raised: What is the value of information? Is it possible to define the monetary value of information? What are the non-monetary values of information? How do users value information and are they willing to pay for it? What benefits does information provide for different parties? Some research about information value has been made during the past few decades, but no generally recognized solutions exist. The studies present different approaches to and frameworks for information valuation and various ways to approach the above mentioned questions (Ahituv 1989, Dué 1997, Iyengar 1996, Repo 1986). However, in many cases the research has been too mathematical in nature and it has concentrated on economics or information processing to such a extent that the applicability of the results suffers (f. ex. Copeland & Friedman 1992, Mock 1971, Lawrence 1999, Sheridan 1995).

At present, many traffic information services are provided free of charge. Information services, however, are diversifying and becoming more sophisticated thus requiring more resources. This has put service providers in difficult position, because users are not very keen on paying for the services, but new innovations are needed to fulfil users' needs and to maximize the profitability of the service activity. (Väliharju et al. 2006.)

## **1.2 Aim of the research**

The objective of this research is to find an evaluation framework for defining the value of transport information. The problem is approached with the following three research questions:

- RQ1. What attributes contribute to information value?
- RQ2. What methods can be used to assess information value?
- RQ3. What information value attributes are relevant to information services and what value assessment methods can be applied?

## **1.3 Research method**

This research follows the logic of deductive reasoning. Deductive reasoning is commonly used in theoretical research when a new research topic is approached by conducting a study of already known facts and theories. This reasoning gives justification for new information if basic theories are valid in the area of research problem. (Olkkonen 1993.)

This research is based on an extensive research of field literature. The first two research questions are answered by finding characteristics which contribute to information value and to obtain what assessment methods already exist. By discussing the research field and various approaches and points of view, this section acts as an outline for the case studies examined in this research. Three transport information cases are approached by using a theoretical framework, which is created in the second chapter of this thesis, and previous research, and by searching different Internet sources.

The literature research and the case study are used to create a framework. This framework can be used as a basis for evaluating the value of transport information. The framework shows what things need to be taken into account in the evaluation process and what assessment methods are most useful ones for evaluating different services.

## 1.4 Conducting the study

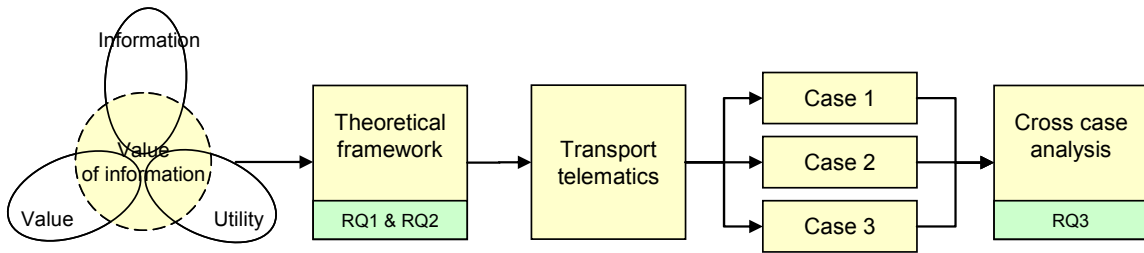


Figure 1. Deductive process.

As mentioned earlier, deductive reasoning is used in this study (Figure 1). First, the information value is approached from the perspective of three basic theories: information theory, value theory and utility theory. This provides a steady foundation for the theoretical discussion and for creating the theoretical framework for evaluating information value. This is done by defining what information attributes affect information value and how, who can make the valuation, what differences there are between different points-of-view, and what assessment methods are suitable for transport information.

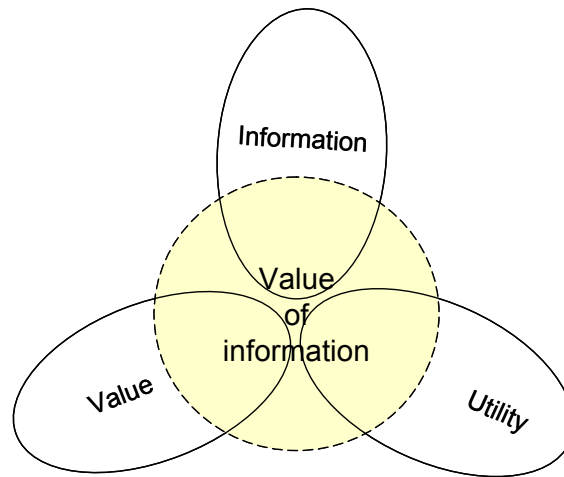
After answering first two research questions, the empirical research area, the concept of transport telematics, and the cases are identified. The steering group of this research at VTT Technical Research Centre of Finland selected three service providers for the case study: Elmi (Finland), Liikenne Tampereella (Finland) and Railinc's (USA) track and trace services. These service providers were chosen, because they represent different types of information services, and, from several options, they were thought to be most suitable for this study. In addition, there was sufficient information available about each case from previous studies to conduct the research but also possibilities for discovering something new. In case study it is necessary to define what kind of information is provided and how, and what the target group is. Then, the characteristics of the information are identified and the relevant information attributes defined for each case. After this, the most suitable assessment methods for defining the value of information in each case are identified and their benefits and usage are listed. Case information is validated by revising the information with appropriate people.

By conducting a cross case analysis the different research topics can be connected together. This manner of analysis aggregates theoretical conclusions and by combining these to the results received from the case studies, we can answer the last research question and create a general evaluation framework for transport information.

## 2. Value of information

### 2.1 Framework

The definition of value of information used in this research is based on three general approaches: information theory, value theory and utility theory (Figure 2). The information theory concentrates on creating, storing and communicating as much data as possible. According to the value theory the basic functions of value are definition, meaning, dimensions, roles and evaluation (Rescher 1982). The utility theory links value and value theory to consumer demands and benefits they can get by using the product. This chapter will consider and deepen these basic theories, but also introduce terminology needed in further discussion.



*Figure 2. Framework of the study.*

#### 2.1.1 Information

Shannon's (1948) Mathematical theory of communication started a new era of information theoretics and information systems. Shannon's Information theory is mathematical and technical in nature and it concentrates on the sending, transferring and receiving of information. The theory does not incorporate the meaning or content of the message, it is only concerned with the engineering aspect of information systems. This information theory presents an important measure of information – information entropy. It measures the average length of a message which can be sent without loss to a recipient (Shannon 1948). Although, the entropy function was originally used to measure the quantity of information, it is, according to several studies, also useful for assessing the value of information. We will consider the entropy function later in this study, but other than that we will not pay much attention to information theory. Before going further, it might be beneficial to make distinctions between different terminologies (Table 1), to avoid confusion in later chapters.

*Table 1. Terminology related to information (Lawrence 1999, Williamson 1982).*

<i>Data</i>	can be symbols, images, text or sound that can be encoded, stored and transmitted.
<i>Information</i>	is data which someone has processed, manipulated or organized in a way which adds knowledge of the receiver. It can be an insight on a new matter or a result of receiving data and the cognitive processing of it.
<i>Statistical information</i>	is new information (something not known before), which is comprehensible and affects what the individual knows.
<i>Pragmatic information</i>	is concerned with the possible impact of statistical information on choices and payoffs, and it thus affects what individual does.
<i>Perfect information</i>	is the maximum potential value of information. It provides direct data, which identify precisely and unambiguously the state that occurs. Perfect information is easiest to assess and the value of the informed decision is the greatest when perfect information is used.
<i>Worthless information</i>	has no pragmatic value and its inclusion or exclusion does not have an effect on a particular decision.

Studies seldom make distinctions between information, information product, information service and information system. Economists often use the phrase value of information when they actually mean the value of a information product or a information system (see Feltham 1968, Hilton 1981). The distinction between these terms is therefore critical for understanding the different aspects of information.

An information product is information presented as an exchangeable good in the market. Information can therefore be compared to goods and services, and it is the information in that information product that creates value for the user. (Freiden et al. 1998, Repo 1986.) Information products are unique in that they can be consumed by several people, at the same time, in various locations. They can be delivered to users in an impersonal manner and the same information is provided to all consumers. The content of an information product is not altered by its consumption, however, information can become outdated. (Freiden et al. 1998.)

Information systems are internal or external data sources which enable the users to search and obtain data messages. They can contain a collection of documents, have the ability to access library databases and the Internet, and also include a set of advisors and vendors of data/information (Lawrence 1999). An information system usually consists of a dispatching centre, service units and a mediating network. Adar et al. (1985) differentiate three forms of information systems: a stationary system has stationary dispatching centre and servers; a check-in system has a stationary dispatching centre and moving servers; and a real-time system is similar to a check-in system, but the servers have access to real-time information through a dispatching center. All these

systems use a different dispatching policy where the stationary system is the slowest and the real-time the fastest (Adar et al. 1985).

### 2.1.2 Value

Value theory investigates what values are and how people value different things. It examines the role of values in explaining human behaviour and decision making, but also the dimensions of value (Rescher 1982). The theory of values is said to be (Dodd 1951, p. 647):

*“A polled population’s desiring of values under specific conditions including time and place, tends to predict their later behaviour.”*

Value, in the sense it is used here, can be divided into personal, social, economical and environmental value. Personal value relates to the things we consider valuable and to how we evaluate, for example, good and bad, and right and wrong. Dodd (1951) defines value to be “anything desired or chosen by someone sometime”. Valuing shows the intensity of a person’s desire for a value and it varies with time, space, socio-economical and situational factors. It is common to explain an individual’s behaviour and choices in terms of his values. Values can be manifested in two different modes: firstly in the form of talk (or thought) i.e. verbal reference to a certain value or inner decision making, and secondly in the form of an action i.e. acting in accordance to a certain value. (Rescher 1982.) Social values are related to the tendency to let other members of the community to affect the individual’s own behaviour. This conscious or unconscious influence can be seen in the individual’s way of valuing things: the possibility to barter a product might change the individual’s appreciation of his or her good and give new value to it according to how much other people want it (Schumpeter 1908–1909). Individuals also have a desire to belong to a group and to be recognized which also affects the way individuals see things. With economic value we usually mean the monetary or the utility value of a product or a service. It can be seen as the market price of commodity (Nykysoomen sanakirja 1985). Adam Smith (1999)<sup>1</sup> also uses the same logic when he gives value two different meanings: value-in-use expresses the utility of an object and value in exchange expresses the power of purchasing that object. Environmental values emphasize ecological health and they concentrate on reducing the effects of pollution, waste discharges and deposits.

Before discussing value in further detail, it might be beneficial to provide some kind of classification of it. There is no standard or widely accepted principle of value

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<sup>1</sup> Online print of Smith’s famous original work: Inquiry into the nature and causes of the wealth of nations published 1776.



classification, but Rescher (1982) introduces six methods for clarifying this field (Table 2). In order to carry out the classification we also need to define how to evaluate value. Products and services can have a generic value or a specific value to someone in a certain time and place. Values can also vary in relation to other products: we can say that one product is more valuable to us than the other, for example one sofa can be more comfortable than another. This is how we assess the relative value of a product. In the strictest sense, evaluation means assessment or measurement of a certain thing compared to its embodiment of value. Values are usually benefit-oriented and people value things on the grounds of getting more benefit as a result of some action. (Rescher 1982.) So, the evaluation of values can be ambiguous and lead to rather varied results in different frameworks.

*Table 2. Value classification (Rescher 1982, pp. 13–19).*

By subscribership to the value	Is the value held by a person or a group?
By objects at issue	The value is evaluated with reference to the group of objects it can be applied to.
By nature of the benefit at issue	Value is classified by the types of benefits at issue. The classification is qualitative in nature, but the value can also be given magnitude and height.
By purpose at issue	The exchange value of an artefact, the bargaining value of a certain resource, the monetary value of a product etc.
By relationship between the subscriber and the beneficiary	Self-oriented values (e.g. success, comfort).
	Other-oriented values (e.g. family-oriented, professional-oriented, mankind-oriented).
By relationship of the value to other values	Values can be viewed as subordinates to other values (e.g. frugality as subordinate to wealth).

### 2.1.3 Utility

Utility theory connects value and value theory to consumer demands and, on the other hand, to the benefits users can get by using the product. Utility is a measure of the relative satisfaction a user can get by using a product or a service. Thus, there are objects which have the capability to produce benefit, pleasure and good, and to prevent pain or unhappiness to those whose interest is considered (Bentham 2000). What we are interested in the utility theory is the possible measurability of utility. Bentham (2000) measures the value of pleasure and pain by first listing different circumstances related to these subjects:

1. Intensity
2. Duration
3. Certainty or uncertainty

4. Proximity or remoteness
5. Fertility: the chance of a value to be followed by a sensation of the same kind
6. Purity: the chance of a value to be followed by a sensation of opposite kind
7. Extent: the number of persons to whom the value of pleasure or pain extends.

Secondly, he sums all the values of all the pleasures on one side and all the pains on the other. This process is applicable also to other modifications of pleasure and pain, for example convenience-inconvenience, benefit-loss, or happiness-unhappiness.

Mosteller and Noguee (1951) approach the measurability of utility with a laboratory experiment, which measures the value of additional money income in a restricted manner. In the first part of the experiment, the subjects participate in a game entailing real money with gambling and risk taking. In the second and third part, Mosteller and Noguee draw a utility curve for each subject based on their behaviour and try to estimate their future behaviour. In fourth part, the predictions are tested in more complex situations. Mosteller and Noguee found out that people usually behave in such a manner that they can maximize their expected utility. They also discovered that it is possible to construct utility curves experimentally, although individual differences are always considerably large, and from these empirical curves it is also possible to estimate future behaviour.

## **2.2 Characteristics of information value**

When we think about information value, we can easily see that there are a few different viewpoints to consider. One of these is of course the attributes of information, considered first, but the information user, firm and society point of views are equally as important. The user is the centre of an information service by demanding information, using it, changing behaviour due to it and so on. The value of information for firms and society is partly dependent on the users and their valuation of information and willingness to pay for it. In this chapter the first subsection considers the information attributes and the later sections discuss the user, firm and society point of views respectively.

### **2.2.1 Information attributes**

One approach to information value is to consider different information attributes. We are interested in information content, quality, and utility, but also in information dynamics and the media used to distribute information.

With information dynamics we mean the impact of time and place, which changes the value of information. The value of information depends on the situation the user is in and on what kind of ‘problem’ the information is supposed to solve. Information is more valuable when it is used to solve a problematic situation than in a normal situation. Users are, for example, more willing to pay for alternative route choice information while standing in congestion than outside peak hours.

Also, the quality of information is defined by the requirements of different consumers. A certain quality level can be acceptable to some consumers but unacceptable to others. The quality of real-time information and the perception of delay are valuable to travellers, especially in incident-induced congestion (Khattak et al. 2003). The data quality can be defined as follows:

*“Data quality is the fitness of data for all purposes that require it. Measuring data quality requires an understanding of all intended purposes for that data.” (Turner 2002, p. 3)*

*“We define high-quality data as data that is fit for use by data consumers.” (Strong et al. 1997)*

There is no general agreement on what are the dimensions of information quality, but in many studies same attributes are repeated. Wand and Wang (1996) have summarized the most often cited data quality dimensions (Table 3) based on comprehensive literature review (Wang et al. 1995).

*Table 3. Citations of information data quality dimension (Wand & Wang 1996).*

Dimension	#cited	Dimension	#cited	Dimension	#cited
Accuracy	25	Format	4	Comparability	2
Reliability	22	Interpretability	4	Conciseness	2
Timeliness	19	Content	3	Freedom from bias	2
Relevance	16	Efficiency	3	Informativeness	2
Completeness	15	Importance	3	Level of detail	2
Currency	9	Sufficiency	3	Quantitativeness	2
Consistency	8	Usableness	3	Scope	2
Flexibility	5	Usefulness	3	Understandability	2
Precision	5	Clarity	2		

Cycana et al. (1996) highlight six data quality requirements: accuracy, completeness, consistency, timeliness, uniqueness and validity. While, Freiden et al. (1998) presents form, accuracy, completeness and timeliness as information quality dimensions. Whereas, the three main dimensions in Ahituv et al. (1981) are content, timeliness and format, but in a later study Ahituv (1989) also includes cost as a dimension. Feltham (1968), on the other hand, would like to place the emphasis on relevance, timeliness and accuracy. Other quality attributes mentioned are reliability (Brownstone & Small 2005), availability (Anderson et al. 2006) and accessibility (O'Reilly 1982). All of these and few other attributes are presented in following table (Table 4) in alphabetical order.

In addition to positive value, information can also have a negative value to valuator. For example, information in the wrong place at the wrong time, although otherwise beneficial, can cause distractions and change the value of information to negative. A good example of this is mobile phone usage while driving, or other distractions like irrelevant information on a taxi driver's driving computer. Information value does not only depend on its capability to effectuate right decisions which provide benefits but also its ability to prevent wrong decisions causing negative value. A decision which is in some cases optimal can be fatal in another. These uncertainties in decision-making and also in the valuation of information just need to be accepted.

*Table 4. Information quality attributes.*

Accessibility	Accessibility means the ease of use and ease of access of information. It includes the information mode and media through information is delivered, but also the reliability of the information system.
Accuracy	Accuracy means that information is free of error (Cykana et al. 1996). Accurate information describes the right phenomena with the right characteristics. Inaccurate information can be misleading and even harmful. (Freiden et al. 1998.)
Availability	Availability refers to how often information is available when it should be (Kulmala & Karhumäki 2007). It can also be seen as a sum of 1) coverage, which indicates from how wide area system provides data; 2) volume, which tells how much information is acquired from one measurement point; and 3) consistency, which is described later in this table. (Anderson et al. 2006.)
Completeness	Completeness refers to how complete the information about subject on-hand is. Incomplete information can be completely useless, cause misunderstandings or have reduced value. (Freiden et al. 1998.)
Consistency	Consistent information is coherent and logical throughout. It describes the degree which information satisfies a set of constraints. (Cykana et al. 1996.) It also demands same quality for all information in the system (Anderson et al. 2006).
Contents	Information content can be divided into information about physical environment and information about behaviour or way of action of other individuals (Hirshleifer 1973). Information content should be organized in a way that it is of use to users (Freiden et al. 1998).
Cost	Cost relates to the attributes of acquiring or providing the information (Ahituv 1989). Only information which cost is less than its perceived value should be produced or acquired (Feltham 1968).
Effectiveness	Effectiveness means the effect information has on user. Effective information may change user's behaviour or his/her way to see the surroundings.
Form	Form refers to the mode and medium information is delivered to the users. In different context of use, users prefer different information modes such as pictures versus text and different media like Internet or mobile. (Ahituv 1989, Freiden et al. 1998.)
Objectivity	Subjectivity in data production process can cause reduction in sources reputation. Coded or interpreted data is of lower value to users and over time the subjective nature of data accumulates questioning the believability and reputation of source. (Strong et al. 1997.)
Relevance	Relevance is an important characteristic when seeking information. Only relevant information is useful to the decision maker and it is expected to affect positively measured payoffs. Relevant information has a positive value, which depends on the changes in decision maker's action. (Fetham 1968.)
Reliability	In the field of transport, reliability is usually related to the use of time and referenced to possible late arrival, waiting or uncertainty. Reliability relates also to random effects like vehicle breakdowns and signal failures (Bates et al. 2001).
Reputation	Information sources reputation comes from the quality of information. Poor quality information leads to poor reputation. A reputation can develop with factual or non-factual basis, but when reputation of poor-quality goes out, the data source is viewed to have little added value to the user resulting in reduced use. (Strong et al. 1997.)
Timeliness	Timeliness refers to how up to date information is (Cykana et al. 1996, Freiden et al. 1998). Time, when data is sent and received, is often critical for decision-making and realized action. It may affect the expected payoff and cause the loss of opportunity (Feltham 1968). Out-of-date information is useless and is usually of little or no value (Freiden et al. 1998).
Uniqueness	Information is unique if it is one of its kind and there is nothing equivalent (Cykana et al. 1996). Unique information gives user possibility to benefit of situation where he/she is the only one having certain information.
Validity	In social sciences validity means the extent where measuring instrument measures what it is intended to measure (Carmines & Zeller 1979). In logic and as an information quality attribute it rather means that with true premises one cannot end up in false conclusion (Encyclopædia Britannica 2007).

## 2.2.2 Valuator

Value of information is highly dependent on the characteristics of the user and his/her decision problem. Examining users' information needs and their decision problems facilitates the understanding of the information use environment and the valuation of information. (Lawrence 1999.) Information use environment includes the surrounding cultural, social and political environments, but it also identifies the potential users and decision problems they face (Taylor 1986). It is also important to consider the providers, customers and suppliers of information, because they all have different goals and the benefits they strive for are different to those sought after by the users, but there is also variation amongst these actors. One should not forget the society viewpoint or mix it with the user viewpoint, when determining information value (Repo 1986). Due to its importance this viewpoint is discussed in the last subsection.

### 2.2.2.1 User

As mentioned earlier, the user is the centre of an information system. In this study, by user we mean people who might need and order traffic information: travellers, commuters, truckers, and so on. Several characteristics, which are discussed next, affect user valuations.

#### *Goals, expectations*

There has to be a demand for a product or a service before we can measure its utility or final value. In his article, Fisher (1968) discusses the terminology of utility and wisely points out that the term utility is actually based on the old economic word "want". He writes about "human wants" which include, for example, wants for what is trivial or useless; wants for what is important, useful or desirable; wants for purpose of real utility; wants for evil and good purposes.

The user's needs and expectations are factors, which contribute the value of a certain product or service. In general, human needs and expectations can vary significantly. The implementation program, the urban area, the state (Turner 2002), the country, socio-demographic factors etc. all contribute to the user's goals, needs and expectations. It is also important for the user to compare the outcomes of an activity to the preceding expectations. This procedure can loosely be described by the expectancy theory (Vroom 1964), which states that individuals first determine the possible actions, estimate the possible outcomes of these actions, and then assess the desirability of each action. The desirability of work derives from extrinsic sources like pay and promotion, from interest in the task and from the pleasure gained by completing a task. This theory can be

applied to the expectations of information service users by stating that the desirability is derived from extrinsic sources like the information provider and information quality, from the interest in the information and the need to acquire it, and from using the acquired information.

### ***Socio-demographic factors***

An individual's socio-demographic environment affects how he/she values, for example, time. The value of travel time savings (VTTS) varies according to an individual's income, physical conditions, behavioural patterns, and perception of time. Also, age and sex seem to affect the value of time (Jiang & Morikawa 2004). When comparing travelling by train to travelling by plane, we can see that income has a contradictory effect on the VTTS. That is, for an individual, both disutility and the alternative uses of time saved when travelling by train are larger than when travelling by plane. In addition, the marginal utility of income for travelling by train is smaller, because it is cheaper, and therefore the VTTS can be expected to be larger than for travelling by plane. However, the results are usually different, because those who can afford to use a plane have higher income and therefore a high value of time, while those travelling by train tend to have a lower income and attach a lower value to time. (Jiang & Morikawa 2004.)

Travellers' initial knowledge of alternative routes and traffic situations has an effect on their valuation of information (see Chorus et al. 2005). Travellers can usually make some estimates of the alternative attributes, for example they can estimate travel time according to different modes and routes. This preliminary knowledge directs travellers when they are acquiring or using new information and enables them to connect pieces of information together and thereby reach the best possible decision.

### ***Travel attributes***

Travellers facing great uncertainty in travel conditions due to an unexpected incident are more willing to acquire real-time travel information than travellers not facing any problems. On repetitive journeys the acquired real-time travel information is combined with initial perception and knowledge of travel times and route choices (Khattak et al. 2003), and after this, the final decision can be made.

Different traffic conditions create varying needs for information and also, place different demands on its content. The type and length of the journey; the route and travel mode chosen; and traffic conditions all affect the value of information. Traffic conditions vary day-to-day, week-to-week according to seasonal, day-of-week and because of specific period effects like school holidays (Bates et al. 2001). Also, traffic

variability and uncertainty have a large effect on the valuation of travel information and travel time savings.

Travel purposes can be divided into three categories: commuting, business, and private trips. Business trips are usually more valuable than commuting or private trips. Different travel purposes also acquire different patterns of time arrangement and different budgets which is a further cause of differences in time valuation. (Jiang & Morikawa 2004.)

### ***Value of (travel) time***

Brownstone and Small (2005) describe the value of time as “the marginal rate of substitution of travel time for money”. On the other hand, the value of time can be seen as a function of work, travel and leisure time, where leisure time encompasses everything outside work and travel. Individuals have a tendency to maximize the time for leisure, which means that a reduction in travel time increases the effective time for leisure, while increases in travel time increase the value of leisure time. Travel time is usually seen as a negative function, because it can cause fatigue and discomfort. (Jiang & Morikawa 2004.) On the other hand, travellers can use their travelling time wisely by reading or working and thus make the value of travel time positive. DeSerpa (1971) defines three kinds of values of time: value of time as a resource (VTR), value of time as a commodity (VTC) and value of time savings (VTS). Jiang and Morikawa (2004) apply this idea further and define the value of travel time savings to be equal to VTR minus VTC plus VTS.

There are three factors that are relevant to the value of travel time: 1) the alternative use of the saved time, 2) the travel environments and 3) the individuals' socio-economical environments. The time saved can be used for the next activity on the agenda, it can be transferred to another activity or it can be used for a new one. When re-timing is possible, the time can be transferred to leisure activities and the value of free time decreases. Long distance traveller usually value time higher than short distance travellers. The following aspects of a travel environment may influence the value of travel time: travel purpose, mode, time and cost, comfort level, surroundings for waiting, expected congestion and perceived security. Also, the individual's socio-economical environment – household income, car ownership and personal activity – which has been discussed earlier, affects the value of time. (Brownstone & Small 2005, Jiang & Morikawa 2004, SPECTRUM 2004.)

The Finnish Road Administration (Tiehallinto) has released a unit value for travel time savings which describes the benefits road users get from reductions in travel time. The value of travel time savings using a car or a bus is on average 25 €/h on work trips and 7



€/h on travel or leisure trip (Tiehallinto 2005). In Sweden, the equivalent values for work trips are 26 €/h by car, 15 €/h by bus, and for travel or leisure 7 €/h (HEATCO n.d.). In California U.S. the value of travel time is 18 €/h on average (Lam & Small 2001). SPECTRUM (2004) suggests that the value of time can be presented as a percentage of the wage rate of different user groups regardless of travel mode. For business travel value is 100% of wage rate plus employer's contribution, for commuters 50–80% of wage rate and for private travel 30–45% of wage rate. According to SPECTRUM (2004), results from case studies correspond well to country-specific time values.

The valuation of small time savings is also an important thing to consider. Is it possible to value a time saving of only a few minutes and is it of any value at all? Mackie et al. (2003) conclude in their report that small time savings should also be considered, but the effect of journey length and income on VTTS variation should be taken into account. The report also indicates that value of small time savings has lower value per minute than large time savings (Mackie et al. 2003). But what if we sum up the small travel time savings of several people? If sixty people save one minute, is the value of this time saving equal to that gained by one person saving 60 minutes?

### ***Change in behaviour***

Traffic flow is basically the aggregation of individual decisions and traffic behaviour. Therefore, understanding the impact of travel information on drivers' behaviour is important for evaluating the performance and the market success of telematics. Traveller behaviour completely determines whether new technologies succeed in providing information which enables travellers to use the scarce road space more efficiently. (Emmerink et al. 1996.)

Different studies (Emmerink et al. 1996, Engelson 2003, Kim et al. 2005, Yang & Meng 2001) have shown that travel information has a significant effect on traveller behaviour. Travel information induces changes in route and departure time choices (Khattak et al. 2003), but also in transport mode selection (Kenyon & Lyons 2003). As a prerequisite for changes in travel behaviour decisions have to be made concerning the destination (where), choice of mode or route (how) and choice of departure time (when) (Jiang & Morikawa 2004).

Emmerink et al. (1996) consider how radio traffic information and variable message sign information affect travellers' route choice behaviour. The purpose of these two traffic information systems is of course to facilitate road users' route choice decision making. The study showed that drivers are more likely to listen to and act according to radio traffic information if 1) the journey is long, 2) there are several route alternatives

and if 3) the driver is under 45 year old, male, and on a business trip. Firstly, this is explained by the fact that the probability of turning the radio on is higher on longer journey, secondly by the opportunity to actually change route thanks to gained information, and finally by higher value of time. Studies have showed that female drivers are more reluctant to change route on the basis of radio traffic information, and surprisingly, the flexibility of arrival time has no significant effect on en-route choice behaviour. The Driver's previous knowledge about alternative routes might have some effect on choosing and changing the route. Results show that variable message signs have similar effects on road users as radio traffic information. In general, it can be seen that commuters are less likely to change their habitual travel behaviour than business travellers tied to fixed arrival times etc. (Emmerink et al. 1996.)

Traffic information can also cause changes in transport mode. Kenyon and Lyons (2003) distinguish three types of traveller information in their research: unimodal traveller information (UTI) relates to a single mode of travel, whereas multimodal traveller information (MTI) concerns several travel modes, yet the information has a single source, and integrated MTI provides information about several modes of travel within a particular information service. In modal choice, the role of habitual behaviour emerges strongly and naturally. The majority of travels are a part of fixed routines, and the journey type is decided and the modal choice made without further consideration. The participants in the survey had their own modal identities, for example car driver or public transport user, and these modal choices were really difficult to change. Information about other travel modes would be used when the regular mode of transport was temporarily unavailable or the optimality of repeated journeys was considered. Easy access to and raised awareness of information could persuade travellers to modal changes and make different modes more attractive to users. (Kenyon & Lyons 2003.)

It is natural that individuals keep to a familiar pattern of behaviour with positive outcomes and eliminate behaviour which has uncertain or negative end results. The operant theory discusses how this mode of behaviour is apparent in the workplace, how reinforcement and punishment can be executed through monetary rewards, personal interaction, or for example, in the form of reports (Lovata 1987). When a user gets positive outcomes from a piece of received information he/she is ready to use it again, and also, the value of information increases.

### ***Benefits, satisfaction***

Users can get several benefits by acquiring and using travel information. Most of the benefits have already been mentioned earlier, but here is summary of the most important ones.

Improved travel reliability and savings in travel time are important to most travellers. Improved travel reliability means that traveller does not have to wait in queues; there are no delays and no late arrivals. Savings in travel time are partly measured by individual travel mode decisions and the willingness to pay to save one minute of travelling time (Jara-Diaz 1990). The time saved in travelling can be used for other activities, for example leisure activities. Travel information gives travellers the possibility to choose between alternative routes and to travel fast, with ease and safely. Especially, the trucking industry can also save money and reduce vehicle usage: with the help of real-time traffic information, truck drivers can choose the right departure time and route, and thus avoid long queues (Kim et al. 2005).

Acquiring travel information can also give the user comfort and pleasure. The comfort level is related to comfort, convenience, reliability and punctuality of the travel services; the traffic conditions such as congestion or free flow; and the weather conditions during the travel (Jiang & Morikawa 2004). Knowledge of traffic conditions and how long the travel is going to take, usually calm users down and makes them behave and think more rationally. Even just the fact that the user receives information about congestion and its extension from an external source, eases the traveller's stress, although he/she is already standing in the middle of the congested road. The received information gives users additional knowledge which helps them to make route choices, travel faster and also gives them the opportunity to inform others that they are going to be late. (Killi & Samstad 2002.)

#### 2.2.2.2 Firm

The second point of view considers the value of information from the firm's side. With firm we can mean three different types of businesses: A Provider is the one with the idea of offering information services to users and customers; Customers are, for example, transport companies, who provide the services to their employee's a.k.a. the end users; Suppliers deliver the information to the customers. Every party has their own expectations and fundamental values they follow when making decisions and valuating information. Risks should also be noticed and their effect on information value identified to ensure as realistic a value as possible.

Different firms have different missions and thereby different valuation methods, but the basic idea is the same – firms want to make profit. Providers are especially interested in customer and user willingness to pay for information, because they seek to get the maximum net cash flow from providing the service. The system is usually financed by the user and advertising fees, and in some cases, with public expenditures (Khattak et al. 2003). Customers are interested in making their business more profitable and their

operations more efficient by acquiring useful transport information from the provider as cheaply as possible. Suppliers can only make profit by setting adequate prices for information transmissions.

User and customer satisfaction and their willingness to pay is an interest to all three parties. Customer satisfaction can be used as a valuation method and as a measure of functionality, because the main point in offering information services is to fulfill customer and user needs and expectations. This can be done by finding out their requirements and hopes, and also by developing a service that provides valuable information. Willingness to pay is partly measured by overall satisfaction and the benefits customers and users can get by using the product or the service. There are also other methods for valuating information. McKenna (2005) presents six well known techniques used in economics: 1) Return on Investment (ROI), 2) Net Present Value (NPV), 3) Internal Rate of Return (IRR), 4) Sensitivity Analysis, 5) Monte Carlo Simulation, and 6) Real Options. He applies them to valuating software products, and some of them can also be used in valuating information from the firms' perspective.

As stated earlier, customers and users value reliable, relevant real-time information. Service reliability can be seen, among other things, as a function of the format of information, the medium used and earlier experiences with the service. The relevance stands for the relevance of the attributes of information the service provides (Chorus et al. 2005). According to a study conducted in three large cities in the US the accuracy of information has significant effect on the value of information to users and the benefits acquired from it. When the accuracy of information drops below circa 85% users are better off not using the service and they get negative benefit from it (Toppen & Wunderlich 2003). Users are also interested in some added value services, like traffic or weather forecasts, or different travel time services. This information adds value to the basic congestion and traffic information, and it might encourage users to pay more for the service.

Typical expenses for the information provider are the costs of acquiring equipment and employing personnel for operation and data collection purposes (Khattak et al. 2003). These expenses form the basic value of the information. By adding other expenses, like marketing and maintenance, and the gross profit to these costs, we can deduce the total value of information from provider's point of view. Typically, economies of scale can be achieved in the supply of travel information, and this is why competition in the traffic information market only exists in large metropolitan areas (Khattak et al. 2003).

### 2.2.2.3 Society

Society is the last viewpoint we consider in estimating the value of information. Society, in a way, is an outsider in the whole information system, although society actually includes both users and firms (discussed separately earlier). Usually, however, the state authorities represent the whole society. In this subsection we consider the benefits of traffic information system to societies.

The benefits of traffic information are strongly dependent on the social structure, the attitudes of residents, the size and structure of viewed area, the volume of commutation and public services. The social structure tells the size of the working population, the amount of car owners and public transport users, the living standards, the behaviour of the residents, and so on. Especially, the behaviour and attitudes of the residents have a huge impact on the outcomes of the implemented information system. The traveller's choice between different travel modes affects the various traffic attributes (volume, flexibility, fluency, safety), but also the individuals own experience of travel – its quickness and comfortableness. Public transport services offer travellers alternative travel modes, but the density of the network and the quality of the service have to be kept as a centre of attention to encourage travellers to choose this option. The size and structure of the viewed area tells us how long a distances travellers usually travel, how many possible route choices they have and what are the most congested roads during a certain time period.

Society's goals (Figure 3) are mostly related to flexible and fluid traffic flow, traffic safety and environmental issues. These goals can be achieved by systematic traffic planning and by advising travellers to more rational traffic behavior. Well-designed and functional public transport with low fares may encourage, for example, commuters to change their travel mode to more an environmental friendly and socially acceptable alternative. If however, commuters continue using private vehicles, they can be informed about optional routes and non-congested travel times, so that traffic stays as smooth as possible. Informed travellers behave more calmly, which also increases traffic safety. Changes in traffic and travel behavior are probably the most important factors affecting the society's valuation of information. Society can achieve its goals through the behavioral change of the travellers. Although, it has been studied that only less than 25% of the traveller changes their travel behavior because of travel information, it is reasonable to expect that at least small changes in the overall travel and traffic behavior. One important factor in improving traffic safety is the automatic emergency call system (e-call). It is an intelligent in-vehicle telematics system which detects accidents and connects to the nearest emergency exchange (Virtanen 2005). The objective of this system is to reduce the consequence of accident by informing the

emergency exchange of the situation etc., and by getting help to the site of accident as quickly as possible.

Society can also fund different information services, if they are viewed to have long-term benefits. Providing the service might not be financially profitable for the companies but if society feels that the socio-economical benefits are very large it can assist in providing the service. In telematics services, this procedure is very typical.

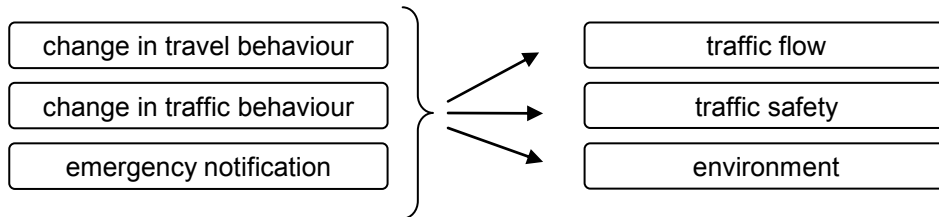


Figure 3. Society's goals.

### 2.2.3 Information service value chain

To get a clearer understanding of the idea of different information valuator we can draw a picture, which shows the value chain of information services, from the collecting of raw data to delivering the information to the users (Figure 4).

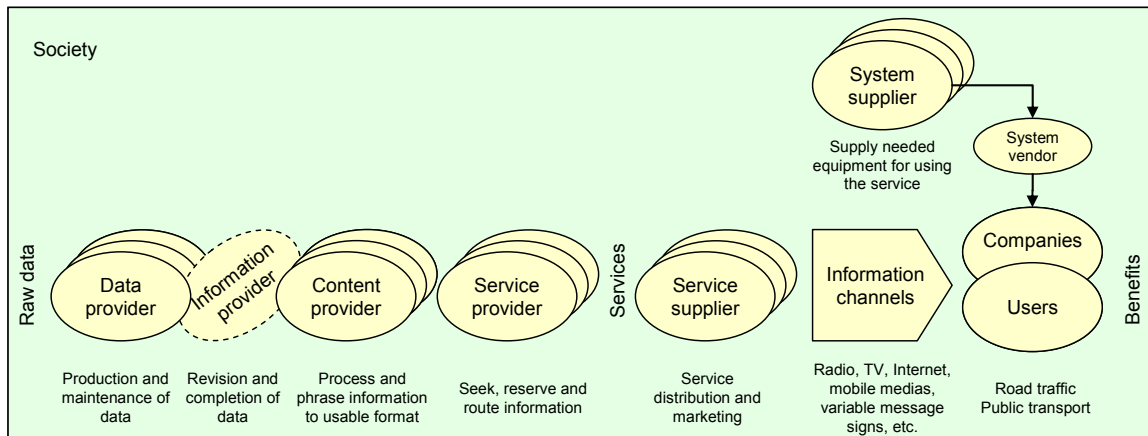


Figure 4. Value chain of information services (revised from Keskinarkaus & Haapasalo 2004 and Mäkinen et al. 2005).

In this value chain, the data provider is the one who is responsible for producing raw data. The collection of data can be done by using automatic systems or manually, for example, by making observations. After the data collection, the information provider processes and combines the data to create relevant information. The content provider combines, processes, and phrases the information further so that it is in an

understandable format, and fits it for different information channels. Service providers seek the needed traffic information with the help of their own infrastructure, or from partners, and service suppliers are responsible of the distribution and marketing of the services. Information is provided to customers through different information channels like the radio, TV, internet, mobile phones or roadside message signs. Multichannel services, where the information is available from different channels at the same time, have also multiplied since the Internet and the mobile media gained ground in the information service business. The system supplier produces the equipment needed for using the service and the system vendor sells them to customers. The end users of traffic information are normal road users, but also companies and organizations. It should however be noted that the value chain does not always include every link of the chain. Data and information providers might e.g. be merged and the service provider might do the revision and the processing of data himself. On the other hand, there might be several providers or suppliers in one stage e.g. 5 data providers produce data for further processing. (Keskinarkaus & Haapasalo 2004, Mäkinen et al. 2005.)

So, in addition to seeing and evaluating information value from the user, firm and society point of view, we can also look at the whole information service value chain and consider information value at different stages of it. Information value varies and changes further along the value chain. Usually, the value increases as we move further, because of the processing and phrasing of the data. But sometimes, the information quality can also decrease: the information goes through so many different parties that after all the modifications and the time spent in processing the data, the information has become irrelevant or outdated.

### **2.3 Assessing the value of information**

It can be easily seen that information has some kind of (economic) value. People are willing to pay for information and attitudes towards information are often similar to attitudes towards other commodities, like food or entertainment electronics. (Ahituv 1989.) Determining information value is important, especially for companies whose success is dependent on putting a right price on information. In several companies' information is also a hidden asset, the value of which only a few understand. These could be the reasons, why many of the following approaches originally evaluate information in the context of organizations and management. But as we can see later, there are also studies on the value of travel information. However, estimating the value of information is not so easy, and that is why this chapter shows several different approaches to information evaluation.

To understand the logic of how information value is assessed, we should understand the nature of the information system. Hilton (1979) describes the information function with following phases: data gathering or observation, communication, storage, presentation and processing. Lawrence (1999) has made a more explicit description of how information value is acquired after different phases of the information system are carried out. This description is presented in Figure 5.

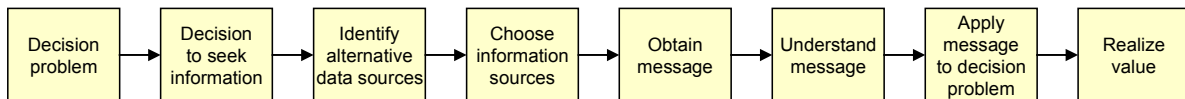


Figure 5. Value chain of decision maker (revised from Lawrence 1999, pp. 8–11).

Value assessment should start off from the decision problem at hand. Inspecting the structure of the decision problem helps to determine the probability of the assessment needed. In this way, users do not have to assess the statistical aspect of the information structure so in depth, in order to assess the value of the information. (Lawrence 1999.)

### 2.3.1 Value-in-use and exchange values

Repo (1986) presents a dual approach to information value, which is based on a philosophical standpoint. Values can first be divided into two main categories – philosophical and practical – as in Figure 6. Philosophical values are inherent (e.g. emotional, ethical and spiritual values); they give background to our behaviour and have intellectual or emotional meaning to us. This is why, they are really hard to detect or specify, although you can usually name them. Practical values can be further divided into two categories: value-in-use and exchange values, which were first presented by Smith (1999) in his book *Wealth of nations*.

Exchange values can be seen as the market-values of information products, services and systems. These can usually be evaluated in monetary terms, and only at this value level can one make direct comparisons of values. These values should be studied using ‘classical’ economic methods, which give useful data to the information provider on the market situation of the information value. Society also operates with exchange values. However, users rarely need to consider exchange values, unless there are several alternative possibilities for seeking information or they are trying to trade information products. (Repo 1986, 1989.)

Value-in-use is the benefit the user gets from the use and the effect of using the information. It should be studied using a cognitive approach, because it emphasizes the use of information and pays no attention to the product, service or system aspects of



information. Value-in-use can be explained with measures like willingness to pay and time savings, but also with actual use (measured by money or time), the way information is used, and according to the benefits of use. The value-in-use of information can further be divided into three groups: expected, perceived and objective values. Expected value-in-use is used in decision-making situations where the individual decides whether to seek and use information product or service or not. Decisions and valuations are often made in terms of the individual's expectations and past experiences, which is why these should be taken into consideration. Perceived value-in-use describes the experience of using information in a particular situation. Objective value-in-use is the value of the real effect the information has on a task and its results. This division is based on hypothesis that users value information when it is used and from the results of the task. (Repo 1986, 1989.)

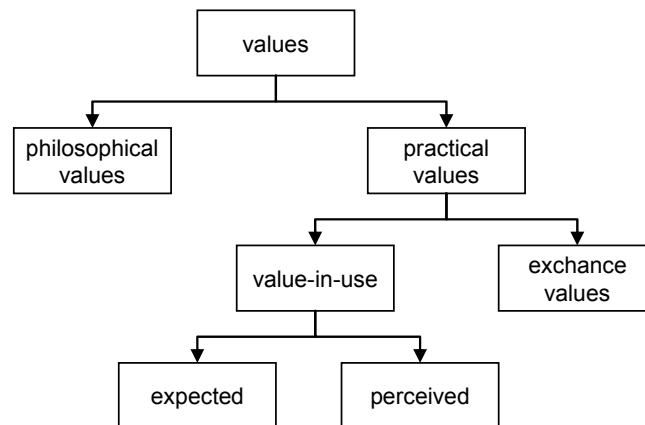


Figure 6. Taxonomy of values (Repo 1989).

### 2.3.2 Normative value

The normative, or information economics, approach resembles the expected value-in-use categorisation presented earlier. It is based on decision theory and is analytical in nature. The information value is determined by the value of the decision or rather by the increased value of the decisions made with the new information (Dué 1997, Iyengar 1996). Thus, normative valuation concentrates on the behaviour, preferences and actions of the decision maker. The objective of this assessment is to derive the expected value of imperfect information and to also consider the fact that decision makers wish to maximize the payoffs yielded from the possible alternatives. (Ahituv 1989, Iyengar 1996.) The basic steps of this approach consist of specifying alternative actions, states, probabilities of states, conditional outcomes, and finally the action environment i.e. the relevant variables, relationships and parameter values. The expected value is calculated for each outcome with an appropriate assessment method (see economic approach

presented further) and the outcome producing the highest expected payoff is used to make the decision. (Iyengar 1996.)

In normative evaluation the basic assumption usually is that decision maker's behaviour is rational (utility theory). Several normative models, like the Operations research model, the Information structure model and models of the Inventory management systems, follow this assumption. Normative models can also make assumptions about different patterns of human behaviour and attain information values, the behavioural patterns can also deviate from rational behaviour. Yet, this model is normative, despite its ability to depict different behaviour patterns, because it asserts what the value should be instead of what it is observed to be. Examples of this model are the Prospect theory and Bounded rationality. (Ahituv 1989.)

Ahituv (1989) sees the normative approach as a "ranking box" (Figure 7). The input to the box is the information system, the output is the rank order and the evaluation of information system and the "box" consists of a set of assumptions e.g. utility theory, prospect theory and bounded rationality. When you change the mechanism inside the "box", a new ranking order may emerge.

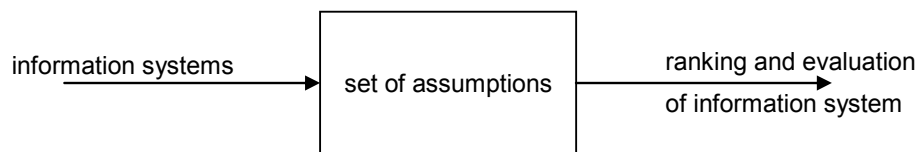


Figure 7. Information evaluation with "ranking box" (Ahituv 1989).

The normative approach holds both research and technical problems. Firstly, it is really hard to model a real life information system with a dynamic action environment, relationships, system components, and so on. Secondly, even though the theoretical model is at hand and mathematical are relationships well defined, it is difficult to integrate real-life cases into the theory. Thirdly, many of the models become so complex that analytical or even heuristic evaluation is not likely to be resolved. (Ahituv 1989.)

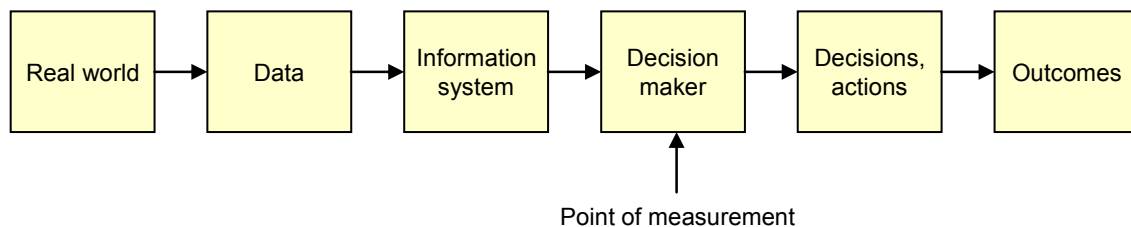
### 2.3.3 Realistic value

The realistic value of information is acquired by providing decision makers different information sets and by measuring differences in their performance. The basic assumption is that changes in information also attribute change in the outcome of the decision problems. The value of information is thus derived from differences in the outcomes. Changes can be as small, such as changing graphic data to tabular, on-line to batch processing, and so on. Studies have also shown that data processing in advance

increases the realistic value of information, but if the user can not find the original data, the value decreases. (Ahituv 1989.) It is clearly apparent, that this approach is similar to objective value-in-use presented by Repo (1989).

The realistic approach is empirical by nature and the information system needs to be prototyped or implemented before the value can be measured. Real-life cases require the measurement of the decision maker's performance prior and after implementation of the information system. These studies are rare, because isolating the effects of an information system from the effects of other factors is difficult and there is seldom enough "before and after" data available. Other experiments are usually based on different information sets where decision maker's actions and performance are recorded and then evaluated. (Ahituv 1989.)

The weakness of the realistic value approach is that the information system has to be implemented before information value can be measured (Dué 1997). Instead of implementing the real system, simulations or mock-ups can also be created. Simulations give a good idea of the final result, but of course require extra effort. It is also expensive if not impossible to simultaneously compare different information systems thus making comparison of different systems difficult (Dué 1997). We also face a problem (seen in Figure 8) when we want to manipulate and change the information system, but the measurement instrument is configured to detect outcomes. Distance between the point of measurement and the object under investigation might also be too long to assure accurate results. (Ahituv 1989.)



*Figure 8. Measuring the realistic value of information (Ahituv 1989, p. 320).*

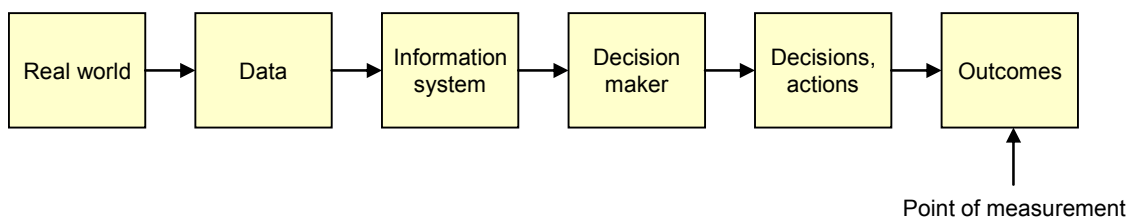
#### **2.3.4 Perceived value**

The perceived, or subjective, value of information is the user's subjective evaluation of an information system. The starting point of this empirical approach is that users recognize the benefits they can gain from the information system and convert these observations into monetary terms or ranking scales. (Ahituv 1989, Dué 1997.)

The perceived value can be investigated by assessing how much user is willing to pay for maintaining a certain information system or some of its features (Ahituv 1989, Dué

1997). Another method is based on semantic scales, the users are asked to mark their preferences of a certain system or its features on a semantic differential scales (usually ranging from 1 to 7). By analyzing these scales, one can obtain knowledge about users' valuations and how they rank different system attributes (see Rescher 1982). A third method assesses perceived value indirectly by observing the intensity of the information system usage. This method assumes that the system is used more frequently, if users believe that it is of value to them. (Ahituv 1989.) The perceived value method is easy and relatively cheap to implement. An extensive questionnaire among users can easily be carried out, for example over the Internet and the results can be analyzed quickly. This is a method used by users to assess information systems on monetary or ranking scales.

The problem with the perceived value approach is that it depends greatly on the individual who makes the valuation, and is thus really subjective. An information system which is highly valued by someone might be judged useless by another. Users might also believe that a certain system is best suited for their purpose although other systems may do better (Ahituv 1989, Dué 1997). Problems are also encountered when trying to determine the characteristics of the information system and their dimensions. Gathered from several studies, a list of information characteristics might include: content, relevance, accuracy, reliability, timeliness, selectivity, flexibility, response time, mode, security, scope, time, place and possession. The dimensions have to be specified separately for every characteristic. For example, the dimensions of form might include readability, logical and simple, but there is no universal agreement on information characteristic nor their dimensions. (Iyengar 1997.) The point of measurement also causes some problems in this approach (Figure 9). Now the object measured, the information system, is closer to the measurement point and the experiment is easier to control, but the real outcomes are still far from the measurement instrument. So, the perceived value might have nothing to do with the real value of the system. (Ahituv 1989.)



*Figure 9. Measuring the perceived value of information (Ahituv 1989, p. 321).*

### 2.3.5 Willingness to pay

Measuring and determining the willingness to pay (WTP) for information content is quite difficult. Travel information today, for example, is mostly free and travellers may underestimate the incremental value of information (Wolinetz 2001).

One method for evaluating WTP is presented by Breidert (2006) under the name: price estimation scene. This method resembles stated preference analysis, but one major difference exists: price is not included as an attribute. The study is made by presenting users a set of different product profiles with assigned prices and asking if they would be willing to buy the presented product. By changing the price attached to a product profile it is possible to find a maximum amount (upper bound for price) and minimum amount (lower bound for price) a user is willing to pay for a product set with the given utility level. (Breidert 2006.) It is easier for customers to choose from assigned prices than assign prices themselves. Price estimation scene is not, however, a new method, Karnes et al. (1995) use the same method in estimating how much users are willing to spend for improvements in shirt quality.

WTP can also be determined from different viewpoints and by several different attributes. For example, WTP for advanced traveller information service (ATIS) is affected by uncertainty, information awareness, information content and information use in addition to situational, contextual and socio-economical factors (Wolinetz 2001). Most of these factors have already been mentioned earlier, and we can see that these factors can easily be applied to other contexts as well. When examining WTP from its own perspective, we can see that it has previously been used as a tool in cost-benefit analysis. Considering an example service, we first have to measure the consumer's WTP for the service, then compare it to provider's expected costs, and determine if providing the service is profitable. (Lee & Hatcher 2001.) It is also important to notice that the WTP for a product or a service needs to be specified in the marketplace. The user's WTP needs to be asked from the real customers in the real marketplace to get realistic and valid results.

Several studies of WTP for travel information have been made with similar results. Customized information, longer journeys, business trips and listening to radio traffic reports increase the willingness to pay for information (Khattak et al. 2003). Studies (e.g. Khattak et al. 2003, Kitamura et al. 1995) suggest that longer journeys and travel times have a positive effect on the WTP for information. This is mainly due to the fact that in these situations there is higher chance of congestion and delays and more alternative route choices. Travel frequency and the reason for travelling affect also WTP, partly because travellers know the route to inquire when travelling on it daily and travel time to work is usually more valuable than time used for personal travel. The

travellers income, travel mode, and, for example, owning a cellular phone might have small effect on the willingness to acquire and pay for travel information (see Wolinetz 2001). For example, male drivers on business trips are more willing to pay for having in-vehicle dynamic traffic information than other travellers (Emmerink et al. 1996). Individuals are also more willing to pay for information if the travel uncertainty is high, information is available only to selected individuals who can choose relatively uncongested routes, and if the perceived benefits of the information exceed the cost of information acquisition. (Khattak et al. 2003.)

WTP also depends on the possible pricing techniques. Users might be more willing to pay monthly fees instead of single payments, or vice versa. This should be noticed when making defining user WTP. Some user groups might prefer single payments, because they do not use the information so often, whereas other groups might prefer monthly fees with a price reduction compared to single payments. All groups and payment methods should be defined as careful as possible to get the most reliable results.

### 2.3.6 Quantitative approach

The common quantitative assessment of a product follows three simple steps: Firstly, the quantity of the product is measured; secondly, the value of one unit of the product is assessed; and finally the total value of the product is gained by multiplying the value of one unit by the total number of units of the product. We may use the same procedure for evaluating information as well. Information quantity could be measured in regard to the number of characters, the number of bits or, for example, the file size. It is not however enough to determine the measures of information quantity, one also needs to assess the value of a quantity. There might not be a direct relation between the size and the value of a data set. (Ahituv 1989.)

The entropy function is an engineering tool used for measuring data quantities. It was first introduced by Shannon (1948) in his Mathematical theory of communication. The entropy function measures the rate of information production and it can also be used as a measure of information, choice and uncertainty. In the entropy function we have a set of possible events with occurrence probabilities  $p_1, p_2, \dots, p_n$  and a positive constant  $K$  as follows.

$$H = -K \sum_{i=1}^n p_i \log p_i \quad (1)$$

H represents the measure of choice or information and has the following properties (Shannon 1948):

1.  $H=0$  if all  $p_i$  except one, which has the value unity, are zero. So  $H$  vanishes only when we are certain of the outcomes.
2. For a given  $n$ ,  $\max(H)$  is equal to  $\log(n)$  when all the  $p_i$  are equal.
3.  $H(x,y) \leq H(x)+H(y)$ . Uncertainty of a joint event is less than or equal to the sum of the individual uncertainties.
4. Changes in probabilities toward equalization increases  $H$ .
5.  $H_x(y)$  is conditional entropy where entropy of  $y$  is weighted according to the probability of getting particular  $x$ . Thus  $H(x,y)=H(x)+H_x(y)$ .
6.  $H(y) \geq H_x(y)$ . Thus uncertainty of  $y$  is never increased by knowledge of  $x$ . If  $x$  and  $y$  are dependent, uncertainty will decrease.

In many fields, there have been studies, which have attempted to use the entropy function for measuring the value of information. These attempts have always confronted the same inherent deficiency of the function: it only accounts for the probability of an occurrence of events, not their meanings. The importance of additional information varies with different situations. (Ahituv 1989, Wegen & Hoog 1996.)

### **2.3.7 Economic approaches**

There are only a few approaches that include the actual mathematical formulas of information value. Williamson (1982) presents students a short introduction to information economics. The objective is to first attain the expected values of sales and the cost of prediction error and then the expected value for perfect and sample information with a simple set of computations. Williamson (1982) presents an example where a manager needs to decide between two different actions on the basis of two possible events to maximize the profit. First, the expected value of sales after different actions is calculated with the estimated demand, the total profit they give and the probability of different events. After this, it is important to calculate the cost of prediction error, which represents the difference between what you could have done and what you expect to. However, this is not a very good method, because it does not take the probabilities of various events into account, and this is why we should consider the expected value of perfect information (EVPI) instead. EVPI is the difference between the expected total profit, knowing which event will in fact occur, and the expected total profit with current information. Again, this is not a very realistic approach, because it is not usually possible to get perfect information but only additional information. The Expected value of sample information (EVSI) is the difference between expected payoff of given additional information and the expected payoff of current information. This is the most realistic of these calculations. A numerical example of this method is presented in Appendix A. (Williamson 1982.)

Hilton (1979) presents a function for information value based on economic and statistical decision theory.

$$U(h) = \int_{y \in Y} \max_{a \in A} \int_{x \in X} \pi(a, x) p(x|y, h) p(y|h) dx dy - \max_{a \in A} \int_{x \in X} \pi(a, x) p(x) dx \quad (2)$$

The information system is denoted by  $h$ ,  $\pi$  denotes the payoff,  $p(x)$  the prior probability density function (pdf),  $p(x|y, h)$  posterior pdf and  $p(y|h)$  pdf over  $Y$ . This formula may look complicated, but actually it is rather simple: it gives the value of information by subtracting the former sum of the utility function from the maximum utility after information utilisation (Repo 1989).

Lawrence (1999) also presents a very similar method for calculating information value. He bases his calculations on the ex-post value of the message  $y$ . It measures the overall impact of the message on the decision maker's payoff and is the difference between terminal payoff under optimal action  $a_y$  and under prior action  $a_0$  in the realized state  $x$ .

$$v(x, y) = \pi(x, a_y) - \pi(x, a_0) \quad (3)$$

In the real world, the decision maker faces different uncertainties because of the ex-ante nature of decision-making. That is why, the available options need to be evaluated and compared with the expected value of a certain function with probability distribution. The expected value of information can be calculated as follows:

$$V(I) = E_y E_{x|y} \pi(x, a_y) - E_x \pi(x, a_0) \quad (4)$$

The expected value of information with information structure  $I$   
 = the expected payoff after using message (prior choosing and using the source)  
 – the expected payoff without the source

$V(I)$  is thus the maximum amount the decision maker should pay for incorporating the information into his/her decision making to expect to be better off (Lawrence 1999). This method is described more precisely in Appendix B.

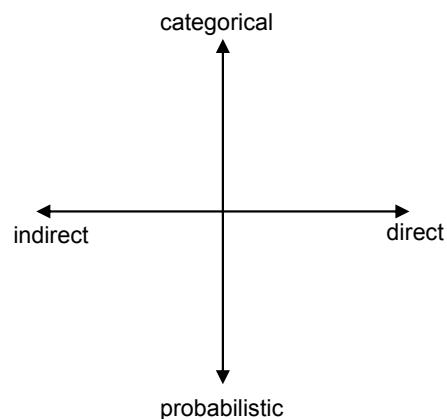
### 2.3.8 Qualitative approach

There is also a need for qualitative assessment of the quality attributes of the information source, such as accuracy, validity, relevance, timeliness, and credibility. It is not enough to only assess the information structure by evaluating and combining the marginal and conditional distributions using the law of probability. Common methods for obtaining advance knowledge of informativeness are commonly studied by



examining track records of past performance and vouching. Once previous knowledge of the information service is obtained, it is quite easy to evaluate its performance and informativeness. If no direct performance records exist, the valuator can assess the reputation and credibility of the information source. (Lawrence 1999.)

The message space can be delineated by the type of information the provider offers (Figure 10). If a decision problem considers, for example, next years demand for a certain product, the demand forecast can be seen as a direct and categorical message (upper right quarter). If the forecast is normally distributed with some mean value and deviation, the information is then direct and probabilistic (lower right quarter). An indirect categorical message could be a document about general economic determinants of demand which requires the user to process the received information in order to make it useful. An indirect probabilistic message contains, for example, a forecast of a nation's Gross Domestic Product (GDB) in the form of probability distribution, and the user has to process this information to derive the demand of a certain product. Categorical messages are more common than probabilistic ones, because the probability of a message is usually defined in more detailed and thus probabilistic messages are more valuable in terms of both time and money. Probabilistic messages are also more complicated and the user confronts problems in processing the information into a decision rule. (Lawrence 1999.)



*Figure 10. Delineation of message space.*

As stated earlier, customizing the message space for the user can improve informativeness and hence increase the value of information. For example, a farmer might need information about how much it is going to rain, not just if it is going to rain or not. If tailored weather forecasts of precipitation are offered, farmer is quite willing to pay for the information to improve decisions and gain pragmatic value. (Lawrence 1999.)

One useful method for assessing information attributes is the analytic hierarchy process (AHP). AHP is a method developed to help individuals in decision-making processes, and in our case, it can be used for assessing information characteristics among other things. Measuring physical quantities is usually easy, because one can use a measure (weight, length, volume), which stays constant in time and space, in normal circumstances. Whereas, measuring, for example, social values or the characteristics of a product or a service are more complicated, because the properties changes over time and space, and in conjunction with other properties. (Saaty 1980.) AHP is really useful method for setting priorities between different unmeasurable qualitative attributes of information.

The analytic hierarchy process uses pair-wise comparisons of attributes. It uses scales for illustrating strength and intensity between the properties at hand and for translating these into priority weights for comparisons. (Saaty 1980.) This method has 4 major steps as follows:

1. State the problem.
2. Determine characteristics influencing the decision-making to establish the comparison. Structure a hierarchy of attributes, sub-attributes, alternatives and properties of alternatives.
3. Build a set of matrices and estimate the relative weights of the characteristics. State the question for the pair-wise comparisons and prioritize characteristics in respect to each other to give them relative importance.
4. Calculate priorities. Divide each element by the total value of the column. Average over the rows and you get the priority vector.

Karnes et al. (1995) has used this method quite successfully for measuring the overall quality of a product from the consumer perspective. McCaffrey (2005) has presented a step by step example of using this procedure in comparing overall quality of product builds.

## **2.4 Problems in assessing the value of information**

A major problem in assessing the value of information is making a distinction between data, information, information system and information service (Ahituv 1989, Repo 1989). Data is piece of message which after cognitive processing is turned into information. Information system is an entity that provides information to individuals. Information service is a service through information can be acquired. It is important to differentiate whether we are evaluating the value of data or information, or are we possibly trying to give monetary value to some information system or a service. In many studies there is no distinction made between these terms which can cause

confusion. Do we want to know how much a user is willing to pay for using an information service, or just the expected value or value-in-use of the information, which are non monetary values? Only a few of the above mentioned approaches can be used for assessing these different values. They are either intended for evaluating the value of an information system (most of them) or just information value. And, also some methods put restrictions on what kind of information can be evaluated. For example, a method of assessing travel information value cannot be used to calculate the value of a piece of information giving several possible route choices (Chorus et al. 2006). Chorus et al. (2006) however state that their method of calculating travel information can not only be used to evaluate the utility value of information, but also to valuate information services in general.

Another major problem is that all the mathematical formulae for calculating information value are very abstract, and they are difficult to apply to real evaluation situations. As Repo (1989) says “fascinating ideas are almost useless in practice”. This can especially be seen in Hilton’s (1979) formula for calculating value of information, because one can easily see the uselessness of it when trying to itemize all the data needed. On the other hand, the value of information is greatly dependent on the individual’s needs, expectations and valuation which are all difficult if not impossible to measure mathematically. “Individuals give different values for the same information depending on context” which is why developing a theory that fully explains value of information does not seem possible according to Repo (1989, p. 80).

On the other hand, problems also arise when we try to define all the information attributes. Information characteristics affect information value indirectly by mediating the decision-making process. These effects are often difficult to predict and one should define the effect of different attributes in several decision-making situations to understand its overall effect (Hilton 1979). One method for the evaluation information characteristics is making pairwise comparison between different information quality attributes (see Karnes et al. 1995, Saaty 1980). This method estimates the value-in-use of information. However, the value-in-use method estimates information value in a rather objective way, and there are only a few indicators showing how information affects the task and the results (Repo 1989). Exchange values can, in some cases, be calculated with economic methods, but these do not take all the information characteristics into account either.

Repo (1986) states at the end of his study: “There is no sense in trying to count the total value of information; different viewpoints and observation levels mean different emphasis.” This is mostly true. The definite reliable total value of information is probably impossible to calculate, because of all the different viewpoints and observation levels, but this does not mean that one should stop trying. The markets will always be interested in the value of information and that is why good guesses are always needed.

## **2.5 Theoretical implications**

The value of information has been studied widely with varying results. In most of the studies, attributes contributing to information value have only been discussed shortly, and instead of information value attributes, researchers have concentrated on creating valuating methods, which approach the subject from different viewpoints and with different emphases. Most of them are ideological, giving reader ideas about what things to consider when evaluating information value, but in some cases a mathematical formula is created in stead. These mathematical formulae can, however, rarely be generalized, and they are thus of use in only few occasions.

This study also paid more attention to the characteristics of information value and provides a possibility to create a general framework to facilitate the valuation of information. The first finding is a framework of information quality attributes, which groups these attributes, so that they can be valued independently. Another discovery is presented in the form of a table, where information quality attributes are attached to value assessment approaches by weighting attributes by their importance in each approach. These results are presented in following chapter, in which the first two research questions are also answered: what attributes contribute information value and what are the methods of information value assessment?

### **2.5.1 Attributes contributing information value**

Attributes affecting information value have only been discussed shortly in previous studies. Different information attributes are mentioned and referred to in several contexts and their influence on information value has been discussed. The discussion has, however, been very limited and only few attribute have been considered at a time. Bates et al. (2001) and Lam and Small (2001) consideres the value of time and reliability, O'Reilly (1982) concentrates on accessibility and Karnes et al. (1995) on the overall quality of information. Cykana et al. (1996) list six, Ahituv (1989) four and Feltham (1968) three of the most important information quality attributes.

Information quality attributes can be classified and arranged to create a general framework for information quality attributes (Table 5). All the attributes and their components must, and should, be selected independently, so that they can be valued separately. This way, they can also be compared with each other and possibly graded in terms of their significance in each situation.

*Table 5. Framework of information quality attributes (modified from Ahituv et al. 1981, Ahituv 1989, Anderson et al. 2006, Bates et al. 2001, Brownstone & Small 2005, Cykana et al. 1996, Feltham 1968, Freiden et al. 1998, Hilton 1979, Hirshleifer 1973, O'Reilly 1982, Strong et al. 1997 and Wand & Wang 1996).*

Attribute	Component	Key questions
Accessibility	mode & media	What is the information format? How is the information distributed? How can information be accessed? Is information accessible when needed? Is the access to information restricted?
	traceability	Can the data source be identified? Can the original data be traced?
	service reliability	Is the information available when promised? Are the mode & media the ones promised?
	service reputation	Are there competitive services? What kind of reputation does the service provider have?
Contents	accuracy	Is the information free of error?
	uniqueness	Is the information same for everyone? Is it possible to get customized information? Is it possible to benefit from being the only one having certain information?
	relevance	Is the information something the user needs? Does the information help to solve the problem at hand?
	completeness	How complete is the information? Is there any deficit?
Availability	coverage	How wide area does the information cover?
	volume	How frequently is the information updated? How much information can be accessed at the same time?
	consistency	Is the information coherent and logical?
Timeliness	real-time	Is the provided information real-time?
	history	Is the provided information based on collected data of past events?
Validity	unambiguous	Does the information include obscurities?
	objectivity	Can the information be considered objective?
Effectiveness	route choice	Can the information make users change their route?
	mode choice	Can the information make users change their travel mode?
	benefits	Does the information create timesavings or increase comfort?
Cost		Is the information free of charge? Does the user have to pay for parts of the information? How much does the information costs?

In addition to information quality attributes, one also needs to consider from whose perspective the information value is evaluated. Every evaluator has their own objectives and evaluation criterions. In this study, three different viewpoints are considered: the user, firm and society viewpoints.

Information value is most often evaluated from the user's perspective. The user's evaluation process is based on goal setting and on having certain expectations. The outcomes of an activity are often compared to its prerequisites and the value of information can thus be found. Other important factors are the user's socio-demographic

factors, which affect the way individual valuates, for example, time or comfort. For instance, income and male-gender have been shown to have a great effect on the valuation of travel time savings (Gunn 2001, Wardman 2001). The value of travel time can be determined by three factors: 1) the alternative use of the saved time, 2) the travel environments and 3) the individual's socio-economical environments. Comfort relates to convenience of travel; punctuality and reliability of the service; and traffic and weather conditions. (Brownstone & Small 2005, Jiang & Morikawa 2004.) In addition to these factors, the journey type and length; travel mode; route and traffic conditions should also be taken into consideration. All these factors affect the user's final decision to use the information, to behave according to it and also the final outcomes. The usage of travel or traffic information creates the possibility to choose between alternative routes and to travel fast, with ease and safely. Knowledge of traffic conditions and the estimated travel time calm users down and can make them behave in a more rational manner.

Firms can be divided into three different groups: the providers of information, the suppliers of information and the customers, who provide information to the end users. All these groups have their own valuation methods, but the basic goal remains the same – they all need to make a profit. The easiest way to measure information value from the firm's perspective is to measure it from the net revenue. How much does information cost and how much can we get by transmitting it forward? Other common variables are user satisfaction and willingness to pay. One value measurement point can be set at user satisfaction, because the most important thing in providing a service is to fulfil the user's needs and expectations. The user's willingness to pay can be measured by studying the overall benefits users can get by using the service.

The society's information valuation methods are maybe the hardest to define. Society encompasses both users and firms, but it is still, in a way, an outsider in the whole information system. We can approach the matter by defining the society's goals and the benefits it can hope to achieve if someone is providing travellers with traffic information. The society's goals are related to flexible and fluid traffic flow, traffic safety and clean environment. These can be achieved by supporting the establishment of information services and by encouraging travellers to use them. A change in the user's travel behaviour directly affects the usage of alternative travel modes and also effects other traffic attributes like traffic volume, flexibility, fluency and safety. In addition to these factors, automatic the emergency call system (e-call) improves traffic safety and reduces the consequences of an accident.

All the above mentioned valutors are part of the information service value chain. The value chain starts off with raw data and the data provider who collects and produces data and ends in the users who get benefits of using the information. Every party in

value chain assess data and information differently according to their own preferences. The value is different at every stage, because the data and the information are constantly modified and transferred forward in the value chain and the valuation is made from different perspectives. At the beginning, the validity and availability may be slightly more important than at the end, and e.g. the significance of timeliness increases along the value chain if the information is meant to be real-time. In following figure (Figure 11) information quality attributes are placed in the information service value chain. The cost and the content increase as we move along the value chain, timeliness instead decreases the longer the information value chain is and so on.

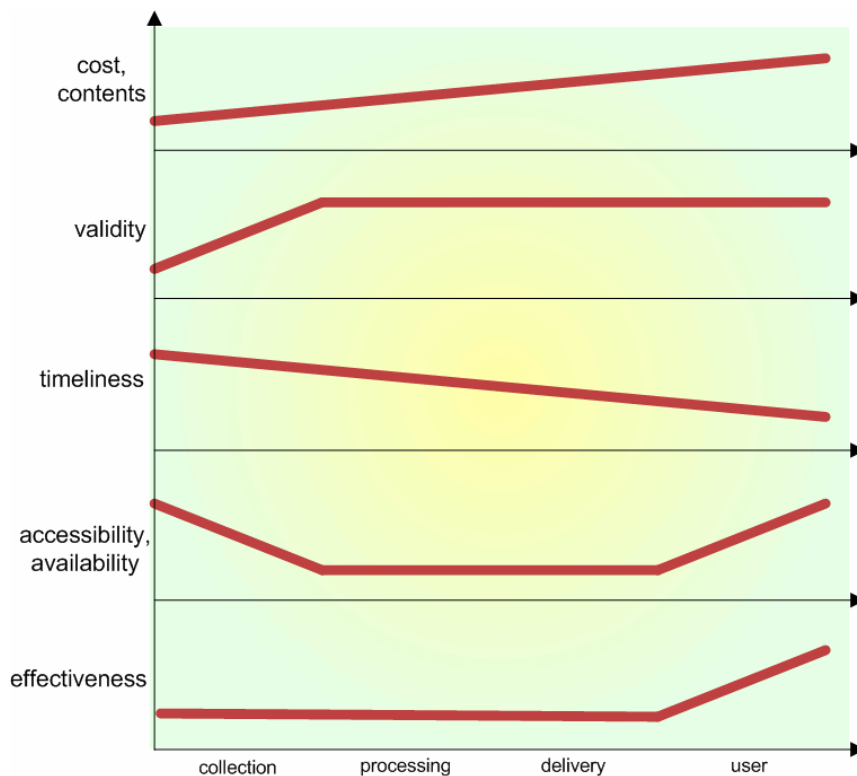


Figure 11. Information quality attributes in information service value chain.

### 2.5.2 Information value assessment methods

Researches have covered several methods of information value assessment. In the normative value approach the value of information is denoted as being equal to the the increased value of the decision made with the new information (Dué 1997). The individual makes the decision whether to seek and use information or not in terms of his/her expectations and past experiences (Repo 1986). The realistic value of information is the value of the real effect the information has on a task and its result (Repo 1986). The value is measured by measuring the difference in user's performance and thus the difference between different decision outcomes (Ahituv 1989). User

benefits are one way of seeing the value of information. Methods for this kind of assessment are perceived value of information and WTP. Perceived value of information is measured by assessing the benefits the user gets by using the information. Monetary or ranking scale assessment can be made by the user or by an external evaluator assessing how much the user is willing to pay for information (Ahituv 1989, Dué 1997). WTP is a method where users are asked how much they are willing to pay for maintaining a certain information system or its features. A better way to measure this, is by presenting users different product profiles with assigned prices and by changing the price to attain the maximum and minimum amount users are willing to pay (Breidert 2006). These methods are especially useful when evaluating information value from the user's perspective.

Other useful methods are the qualitative, quantitative and economic approaches. Information characteristics can be evaluated with the qualitative assessment method. It is a useful and important method for both the decision-maker and the firm. Information characteristics and quality can be assessed by using direct records of past performance, or by assessing the reputation and credibility of information source (Lawrence 1999) or with the Analytic Hierarchy Process (AHP) (Saaty 1980). AHP is a method of setting priorities between a set of unmeasurable attributes of information (Saaty 1980). There are only few approaches to assessing the monetary or otherwise quantitative value of information. To measure information quantity by means of its volume, or for example according to the number of characters (Ahituv 1989, Shannon 1948) is not very convenient. More useful methods are presented by Williamson (1982), Hilton (1979) and Lawrence (1999). They all basically share the same method: the information value is the difference between maximum expected payoff (= maximum utility) with and without received information and it can be calculated in monetary terms.

All above mentioned approaches assess the value-in-use of information. One can also distinguish between exchange values of information, which can be seen as the market-value of an information product, a service or a system. These can usually be measured in monetary terms. (Repo 1986.) Another way of measuring the value of a system or a service is by studying the users' willingness to pay for using the service. This is not, however, a very good technique, because most of the users would not pay anything if service is currently free.

Information value assessment methods can be combined with information quality attributes, as mentioned earlier. This model helps to understand the thought behind the different value assessment methods and it also facilitates the evaluation process. In Table 6 information quality attributes are listed on vertical axis and assessment methods on horizontal axis. The mark x in the intersection means that the attribute in question is somehow important for that assessment method and should therefore be weighted. This



does not mean that attributes with empty intersections do not have any effect, but only that they have less significance than the weighted ones.

*Table 6. What information quality attributes are weighted in different value assessment approaches?*

Attribute	Component	Normative value	Realistic value	Perceived value	WTP	Quantitative	Economic	Qualitative
Accessibility	mode & media		x		x			x
	traceability		x					x
	service reliability				x			x
	service reputation				x			x
Contents	accuracy	x	x	x				x
	uniqueness	x	x	x				x
	relevance	x	x	x				x
	completeness	x	x	x	x			x
Availability	coverage	x		x	x			x
	volume	x		x	x	x		x
	consistency	x		x	x			x
Timeliness			x	x	x		x	
Validity	unambiguous	x	x	x				x
	objectivity	x	x					x
Effectiveness		x	x	x				x
Cost			x	x	x			x
Notes:		Value of decision.	Value of outcome.	Valuation made by valuator.	What attributes can users see?	Value on the grounds of e.g. data quantity (5 kB).	Attributes are embedded in the mathematical formulae thus they are not weighted here.	Comparison of quality attributes with each other.

### 3. Empirical case studies

Travel information services are useful for people who want to plan their journey in beforehand, and possibly make changes during the trip depending on the actual traffic situation. The objective of providing travel information services is to improve traveller comfort and awareness, but also to improve the safety and mobility of road networks. (FIST 1998, TIS EG 2006.) This chapter discusses different travel information services and concentrates on three empirical cases. The first section explains what travel information is, and describes what kinds of traffic information services are available, and how they are of use to travellers. The following sections consider the Elmi-service, which provide real-time information about bus arrival times; the Liikenne Tampereella service, which provide real-time information about the traffic situation in city area; and Railinc, which is a service for tracking and tracing shipments. The cases are approached by using the theoretical framework created in Chapter 2. The main emphases of different valuator perspectives in each case are presented in Table 7.

*Table 7. Main emphases in valuating transport information cases from different valuator perspectives.*

		Elmi	Liikenne Tampereella	Railinc
User	goals, expectation, values		x	x
	socio-demographic factors	x	x	
	travel attributes	x	x	
	value of travel time		x	
	change in behaviour	x	x	
	satisfaction, comfort	x	x	
Firm	goals, expectation, values			x
	users satisfaction	x	x	x
	users willingness to pay			x
	expenses			x
	profit			x
Society	goals, expectation, values	x	x	
	social structure	x	x	
	users behavioural change	x	x	
	public services	x		
	benefits	x	x	

### 3.1 Travel information services

Traffic information can be real-time or static, and both of these can be used for informing travellers about traffic conditions. Static information changes infrequently and is usually known in advance. Real-time information can be divided into pre-trip and on-trip information depending on whether the information is acquired before the trip, for example, from the internet, or during the trip from the roadside, the radio, mobile services or some in-vehicle equipment (TIS EG 2006). Static information is, in a sense, more reliable than real-time, because when one provides real-time information, freshness, availability and accessibility become key factors. The information can be given in the form of pictograms (road signs), pictures, text (internet) and/or voice (radio).

Transport information is useful to almost anyone travelling or transporting who has benefits to gain or resources to lose. For the trucking industry and transportation agencies the most valuable information concerns freeway incidents, construction sites, traffic volume, roadway occupancy, vehicle speed, travel time to traverse a highway, queues, travel times on alternative routes and weather (Golob & Regan 2005, Margiotta 2002). Waiting in congestion reduces company productivity and increases idle time and costs. With real-time traffic information (RTTI) companies can save money, reduce vehicle usage and improve their service level and reliability (Kim et al. 2005). All the above mentioned information is also useful for 'normal' commuters driving daily on congested routes, but for them the benefits are mostly related to travel time savings (Brownstone & Small 2005, Jiang & Morikawa 2004).

Companies and, for example, 3PL's (Third-Party Logistics providers) produce information about their own shipments to help supply chain management and customer service. Other travel and weather information is usually ordered from outside. (Laakso et al. 2006.) In Finland the Finnish Meteorological Institute collects i.a. weather data and Destia collects i.a. road and traffic volume data. Collecting data just to provide customers traffic information is not profitable, because the customers' willingness to pay is very low. That is why it is good to take advantage of existing data from different sources and formulate it to meet the needs of the customers. Laakso et al. (2006) recommend that the market of traffic information services should first be approached on the ground of business-to-business (B2B) marketing and later, when the time is ripe, the supply is directed to customers (B2C).

**Real-time journey time prediction information** provides instantaneous journey time estimations, mostly in urban areas. Information can be acquired and used pre-trip or on-trip, depending on the possibilities the information systems provide and traveller preferences. In some areas, for example in Scotland and France, short-term journey time

predictions also exist. A new emerging service, which is in high demand, is personalized journey time prediction. (TIS EG 2006.)

**Roadside information** is on-trip information usually telling about speed limitations, warning about deer or the gravel on the road, and so on. These permanent road signs have been accompanied recently by variable message signs (Figure 12), which include text and/or pictograms. These signs have messages changing on the basis of traffic and weather information. (TIS EG 2006.) These kinds of signs have been already introduced in major railway stations, bus stops, and so on and now on roadside they give information about hazards, congestion, rerouting possibilities etc.

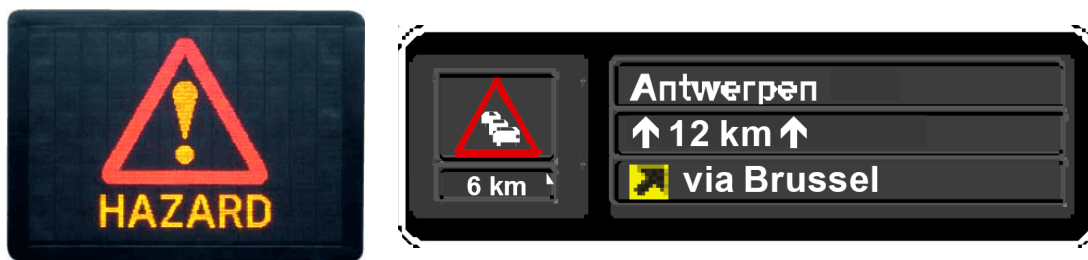


Figure 12. Variable message signs (Centrico n.d., VMS n.d.).

**Telephone information** systems can be staffed by human operators or they be fully automated. In the U.S.A and in Canada telephone information systems are already a widely used way to obtain transit information. For example, in Canada the “560 system” is automated and it gives arrival times of the next two buses at a specific stop, if the bus stop is included in the system. The system also notifies the user if there are any delays or other problems on the bus route. (FHWA n.d.)

**In-vehicle information** can be transferred to travellers via radio, RDS-TMC, digital radio, mobile phone, navigator or PDA equipment (TIS EG 2006). It is common for local and national radios to give traffic information newsflashes about traffic incidents, congestion and weather. RDS-TMC is an internationally accepted standard for broadcasting traffic data on FM radio (ITIS Holdings n.d.). It is also used for delivering traffic information to on-board satellite navigation systems. (RDS-TMC n.d.) Real-time on-board information can be about speed limits, traffic signs, regulations, weather, road condition and maintenance, accidents on main roads, alternative route choices, and so on (e.g. [www.varopalvelu.fi](http://www.varopalvelu.fi), [www.getmethere.co.uk](http://www.getmethere.co.uk)). In-vehicle information serves travellers’ decision-making concerning route changes, speed, and travel time and travellers can also prepare for problems and possible late arrivals.

**Internet based services** provide travellers information similar to what they can also get in-vehicle. The most common services are public transport routes, route planners and timetables (e.g. [www.linjakas.fi](http://www.linjakas.fi), [www.reittiopas.fi](http://www.reittiopas.fi)). Also, information about unusual

traffic conditions, traffic changes and traffic fluency can be shared real-time on the Internet (e.g. [www.liikennetampereella.fi](http://www.liikennetampereella.fi), [www.trafikken.dk](http://www.trafikken.dk)). Added value information or modules can inform travellers about travel time, traffic forecast and weather conditions. The best Internet based services present real-time traffic status with cartographic maps, provide written explanations of the situations, possibly even contain a route finder, and supply traffic forecasts for each day or even every hour. Some services also provide webcam images from generally congested roads and of weather situations (e.g. [www.tiehallinto.fi/alk](http://www.tiehallinto.fi/alk)). Many Internet based services also have WAP-possibility, which means that travellers can get the same information on-trip to their mobile phone.

**Freight services** provide both pre-trip and on-trip information for transport companies and truckers to help them plan optimal routes, choose parking spaces and rest areas, and get real-time traffic and weather information, and so on. TruckInfo ([www.truckinfo.ch](http://www.truckinfo.ch)) is a web portal for Switzerland and the Alpine region. Freight Service Portal ([www.freteuroservice.com](http://www.freteuroservice.com)) contains links to various real-time traffic information, multi-modal information maps, specialized services, road restrictions and so on. The portal mainly covers Belgium, the South East of England and Western France. (TIS EG 2006.)

**Multimodal interfaces** will provide travellers easy-to-use and comprehensive travel information and ticketing services. In the future, it will be possible for travellers to plan their journey in advance from and to anywhere they want by using any travel mode. And, on the side, they can also get information about real departure and arrival times, and possible disruptions on the chosen route. At the end of the process, the traveller also has the possibility to buy all the necessary tickets from the different transport operators and ticket services. (TIS EG 2006.) Examples of multimodal interfaces under development include Rejseplanen ([www.rejseplanen.dk](http://www.rejseplanen.dk)), which is a service for trains and buses in Denmark, and the TTIS portal ([www.travel-and-transport.com](http://www.travel-and-transport.com)) for multimodal travel information in Denmark, Finland, Norway, Sweden and Germany.

## 3.2 Elmi

### 3.2.1 Description of the service

Elmi is a passenger information service for Southern Espoo (Finland) public transport. Passengers are provided information about the true arrival times of buses with the help of real-time positioning information and scheduled arrival times for other buses. There are also different features, which help drivers and transit operations, and there is also a possibility to have traffic lights benefit the vehicles. The main objectives for

implementing the system were to improve the quality of service and to increase the number of travellers using public transportation. (Pesonen et al. 2002.)

The system is based on a global positioning system (GPS) for buses and on radio data transfer between buses and control centres. When a bus is connected to the system, it transfers real-time location information to the control centre, which passes the estimated arrival time of the bus to the information boards on the bus stops. The system also includes displays for drivers, the displays tell the drivers if their bus is ahead or behind schedule. In 1998 the system consisted of 300 in-vehicle equipment (now increased by 30), 3 radio base stations and 20 bus stop displays and monitors. (Pesonen et al. 2002.)

The information provided for customers is presented in Figure 13. Bus stop displays show the theoretical waiting times for certain bus lines in minutes. Monitors show the waiting times for all busses passing by the terminal. The diamond in front of an arrival time means that the waiting time is based on the normal timetable, not the real-time follow-up system. The bus pictogram implies that bus is just arriving at the bus stop. (Pesonen et al. 2002.)



Figure 13. Elmi information board on bus stop and monitor in bus terminal (Pesonen et al. 2002).

The current Elmi bus stops have measured around 18800 get-ins and get-offs per day in 1995 and almost 25000 in 1999. So, the amount of get-ins and get-offs per day increased by 33% in four years. In year 1999, there were around 106000 travellers per day travelling on Elmi-lines and the amount of travellers had increased by 7,5–10% by year 2001. However, there have also been other changes made to the bus network, so, the credit of the volume increase cannot be solely given to the Elmi-system, but also to the overall improvements of the public transport system. (Pesonen et al. 2002.)

## 3.2.2 Characteristics

### 3.2.2.1 Information attributes

To understand the meaning of different information attributes in the Elmi-service, an analysis is needed to be conducted. The information quality attribute framework presented in Table 5 provides an easy way of looking at the different attributes and their relevance in this case.

The accessibility of information is quite important. In this case, the users do not have the possibility to affect where they can acquire the information, and this is why the service provider is responsible for placing the information in places that are obvious enough for the information to be of value to the users. Elmi provides the users real-time information about bus arrival times by showing the schedules in an easily noticeable and understandable format on the information boards and monitors at the bus stops. The benefit of using less time for finding the bus arrival times and also the less frequent use of paper timetables (Pesonen et al. 2002), refer to the fact that the information is accessible. Service reliability is also important, because users are highly dependent on the timeliness and relevance of information. They need to get the right information in the right place at the right time. The reputation of the service provider does not have an effect on the information value, because there is only one system and users cannot make a choice between alternative services.

According to the study, bus arrival time information is complete and relatively accurate. Some problems were detected with the bus sign going disappearing from the display before the bus had passed the bus stop, but actions are taken to solve this problem. (Pesonen et al. 2002.) Information is accessible to everyone using the bus lines in the system, so the users do not have the benefit of being only ones knowing certain information, and thus information uniqueness can be left out of consideration. We can be sure that the provided information on the information boards is relevant, and it thus increases the value of the information.

Information timeliness and its real-time quality are very important in this case. However, according to the study this area needs some improvements. Although, the buses send location data to the control centre at least every 30 seconds, it is not a guarantee that the busses arrive at the bus stop at the time shown. According to the study, the system works properly when waiting time is 20 minutes, with a waiting time of 10 minutes the system does not work so well, and when the estimated waiting times vary between 0–10 minutes, there is clearly a need for improvement. Especially, when the waiting time disappears from the information board, before the bus has passed

the bus stop. So it can be concluded that the real-time system is not serving the users as well as it should be. (Pesonen et al. 2002.)

One objective of the service is to make the usage of public transport easier, increase its attractiveness and encourage more travellers to use it instead of a private vehicle. Information can indeed have an effect on the users' travel mode choice, but it also affects line and route choices, and gives the users the possibility to use the waiting time better. On some occasions, it can even encourage users to walk short distances instead of waiting for a certain bus for a long time. The provided information is free for users, so the cost of information does not have a negative effect on the information value. It might, however, have a positive effect on the perceived value, because it increases the users' knowledge and facilitates their decision-making.

### 3.2.2.2 Valuator

In addition to information attributes, it is useful to look at what kinds of expectations different valutors have of the Elmi-service and what kind of effect the information has.

User expectations of the service might relate to reliability of the service and the schedule information, in addition to, the ease of travel created by having access to information telling which buses come next and what is the waiting time. The goals are probably the same as in all urban travelling: travellers want to get to the destination fast, safely, with ease and trouble-free. If the users feel that the provided real-time arrival information on the buses fulfils these goals and expectation, we can say that the information has a positive value. This is not, however, all there is to it. The user's socio-demographic factors, like income, occupational position, gender and so on, affect how the information value is felt. Elmi users are from all age groups, and the majority of them (62%) are women (Pesonen et al. 2002). Almost a third of Elmi users are pupils or students, and slightly over 50% are in employment (Pesonen et al. 2002).

The social structure and the characteristics of the viewed area, the city of Espoo, also affect usage and the general opinion on Elmi. Espoo is the second biggest city in Finland with over 231 000 citizens. There are over 98 000 cars and 512 road traffic accidents a year (year 2004). With almost 6000 daily bus departures the public transport service covers one fifth of the total inter city motor traffic. Traffic has increased each year, but at the same time public transport has been developed. (City of Espoo Pocket Statistics 2006, [www.espoo.fi](http://www.espoo.fi).) The socio-economical benefit of Elmi was measured in year 2002 in terms of a benefit-cost ratio. It was measured to be 1.3 in present scope of the service, which means that the system is profitable. (Pesonen et al. 2002.) From the society point of view, it is important to increase the usage of public transport and reduce



the number of private cars in traffic. This improves traffic fluency and safety, reduces pollution and congestion, and thus improves overall well-being of the travellers. Instead of using their own cars, commuters are advised to use public transportation, and Elmi has been created to promote this goal. If Elmi reaches its original goals and expands to a wider area successfully (as it seems to be doing), the value of provided by the information also has a great value to society.

The value of information as perceived by bus drivers derives from two sources: the fact that travelling has become easier for users, also helps the bus drivers, and the driver display show additional information. Thanks to the information boards at the bus stops, travellers are prepared to stop the bus, and take out their money or ticket in advance, which in turn makes the get-ins more fluent. The information boards also reduce the number of questions presented to the drivers about forthcoming buses and other possible line selections. In theory, driver displays show if bus is ahead or behind schedule, and thus help drivers to keep on schedule and to improve timekeeping. According to study, over one fifth felt that the system helped their work. However, 10% felt that the system hindered their work by increasing stress in situations where the driver could not affect the driving speed. The driver displays thus have a positive effect, especially, in quiet times, but while driving in congestion the drivers can hardly affect the driving speed and timekeeping. (Pesonen et al. 2002.) The benefits of the system and the driver display also depend greatly on individuals and their capability to adjust their actions according to the provided information and the current traffic situation without stress and disturbance.

For the bus operators the concrete benefits of the system are easier transport planning and driver follow-up, and the system also reduces operation expenses. Bus operators think that the system also improves customer satisfaction and image of bus transport. One major disadvantage has been that the system binds the fleet on a certain line and thus complicates fleet arrangements. (Pesonen et al. 2002.) The value of information is thus the sum of easier transport planning and the increased bus usage. The latter is directly related to the profit, and we can say that most of the information value formed by the payoff made.

### **3.2.3 Value of information**

To assess the value of information provided by Elmi, it is useful to look at previous research and interviews made in relation to it. The most useful is perhaps a study commissioned by the Ministry of Transport and Communications Finland to assess the impacts and socio-economical profitability of Elmi (Pesonen et al. 2002). The evaluation cycle was carried out before (1996) and just after (1998) the implementation

of the system and then five years afterwards in 2002. In the study, an impact and cost-benefit analyses were made to gain knowledge of the investment and maintenance costs as well as user benefits. This study gives us the possibility to approach value assessment by studying user benefits and by using the perceived value method.

Bus stop interviews and sensitivity analyses were conducted to find out the value of the information impact. In bus stop interviews the most important user benefits were identified as follows (Pesonen et al. 2002):

1. Easier travelling
2. Reduced uncertainty
3. Better line selection
4. Better usage of waiting time
5. Better travel mode selection.

Other user benefits are listed in Table 8.

*Table 8. Benefits of having information boards and monitors at bus stops (Pesonen et al. 2002).*

%	1998	2002
The timetable is in a better place and easier to see (2002)	–	36
I can choose the best bus line	13	19
I know, that the bus has not gone yet	19	18
I can use the waiting time better	6	14
I can wait more comfortably	6	13
The waiting time feels shorter	5	8
The information is more reliable	45	3
I can choose another travel mode (2002)	–	3
Something else, what	1	2
Total	95	117
N	680	759

In the study, the value of user benefits was evaluated by using five components, which were decided to be the most important ones: the benefit of better travel mode selection, better usage of the waiting time, better line selection, lower uncertainty and less time needed to find out arrival times (Figure 14). In this study, the benefits are assessed against the number of users gaining benefits and time savings. The monetary value is then derived from the matrixes on the basis of the most realistic value. In the calculations, the value of time was 5,26 €/h, which is an estimate made by Tiehallinto

(the Finnish Road Administration). (Pesonen et al. 2002.) The total user benefits are around 342 000 €/year (Figure 14) and with 20% of the 12500 travellers/day benefiting from the system (Pesonen et al. 2002), we can derive the monetary benefit of the information system for a single traveller, this is approximately 0,38 €/user/day. Can we make the assumption that, this value of user benefits equals the information value from the user's perspective?

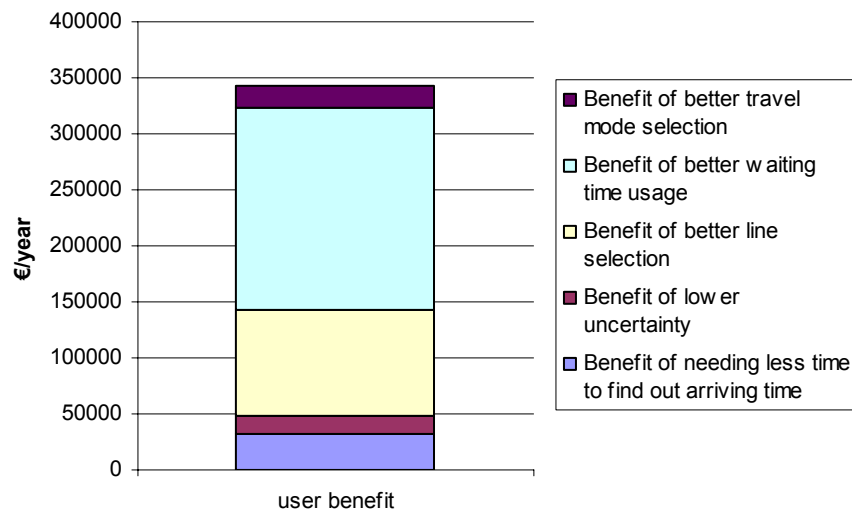


Figure 14. User benefits in current extent of the system with year 1999 travel volumes (Pesonen et al. 2002).

When examining conducted research and its result, and comparing it to different information value assessment methods, it is quite easy to conclude that the value of information indeed equals the value of user benefits when evaluating the value from the user's perspective. The study clearly follows the perceived value method in which users identify the benefits of the system. The most important benefits are then transferred into monetary terms by defining, what is the time saving in the case of each benefit, by using the generally approved value of time (€/h). This information value is suggestive, and for example, ranking scale assessment would also be as good, but not so easily comparable with other similar assessments.

Approaching information value from the point-of-view of user benefits is probably the best method in this case, because the service is very user centred. The assessment of the user benefits gives a good picture of the users' values, their valuating methods, what is valuable to them, and whether or not the service fulfilling all their needs. Enquires and interviews of a wide range of customers usually give reliable results of user benefits, and are thus recommended as a method for this kind of assessment. Some weaknesses, like in all research methods, however, do exist. For example, irrelevant or badly

formulated questions and users' presumptions on what they are expected to answer may distort or give false results.

Another possible valuation method is the realistic value method. In this method, the basic idea is that changes in information attributes also change the outcomes of decision problems. The value is then derived from the difference between the different outcomes. Data processing and changes in the way the data is presented may increase or decrease the realistic value. In this case, users are offered bus schedule information through variable message signs on the roadsides, in addition to paper timetables. Users can therefore reduce the usage, or stop using the old paper information altogether, if they feel that the new information is more valuable to them. Here the valuation can be done by comparing the paper and roadside information with each other, and by defining the pros and cons of both formats the value of the roadside information can be found.

### **3.3 Liikennetampereella.fi**

#### **3.3.1 Description of the service**

Liikennetampereella.fi is a traffic information service for the Tampere city area (Finland). It provides travellers an easy way to check if congestion or other traffic situations are on the way, by mobile phone or through the Internet (Figure 15). For profiled information and mobile usage, the users need to register, but in general, the service is free of charge. (Liikenne Tampereella n.d.) Registered users can profile their needs and acquire information about certain routes, changes to the normal traffic situation, and traffic volumes, and they can also receive the news. Without registration, travellers can still find information about the traffic situation in the Tampere area, but of course, without personal settings. Most of the daily users are non-registered. (Laakso et al. 2006.)

The data for the service is collected from three different sources: taxis, traffic light systems, and automatic traffic monitoring stations (ATMS). During peak periods taxis collect a great amount of information, but at other times, the system relies on the other two information sources. This backup is necessary to insure that the system is not relying only on a single source, and can, therefore, provide reliable information at all times. There are 200–300 taxis collecting floating car data (FCD) about traffic fluency or its jamming in the Tampere city area every day. The signal control system collects data in 15 minutes and ATMS in 5 minutes chunks. The application collects data automatically from all these sources and examines possible changes and emergencies with the help of its own traffic model criterion. With the help of the application service the provider creates information in the form of maps and text for HTML-browser and

text information for WML browser. The taxi drivers get the information straight to their driving computer in graphic and text format, and road maintenance gets information about traffic fluency and changes in it in the form of graphic maps and XML message. The end users get the information about the traffic situation in the city areas major roads through the Liikenne Tampereella multichannel service. (Laakso et al. 2006.)

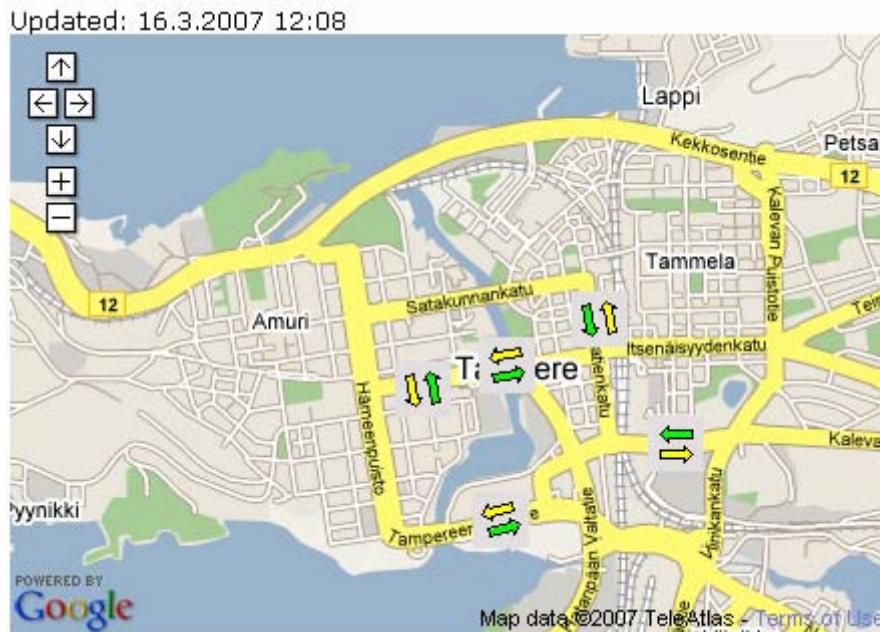


Figure 15. Liikenne Tampereella traffic map Friday 16.3.2007 lunch time. Yellow arrow shows where traffic is slowed down or traffic conditions are weakened. (Liikenne Tampereella n.d.)

### 3.3.2 Characteristics

#### 3.3.2.1 Information attributes

As in all information services, accessibility is one of the most important factors. The information mode and media used to distribute it affect the information value directly. The information provided by Liikenne Tampereella can be accessed from the Internet or by mobile phone, providing it contains a wap-browser. Information is in the form of maps and text (Internet) or just text (wap), and it is easily accessible both before trip or on-trip. Some users might be interested in the information source, but system does not directly provide this information. The service reliability is quite important, because the information needs to be available when it is needed, and the service is quite useless if it e.g. does not work during peak periods. In this case, the service provider's reputation does not need to be considered, because Liikenne Tampereella is the only information service of its kind in this area.

The information content is highly specified. The information accuracy is some what important but not vital, because small errors in the information, supposedly, do not impede the users from arriving at a destination, or harm him/her at any way. According to the study made about the service quality of Liikenne Tampereella, almost three fourths of the respondents thought that the provided information was accurate or really accurate (Laakso et al. 2006). When considering the significance of information content, relevance and completeness should be emphasized instead of information accuracy. The information about congestion needs to be relevant and cover as large an area as possible. This leads us to the importance of information availability. Information coverage, volume, and consistency are all really important attributes in this service.

Timeliness is also a very important factor when acquiring and using information from the Liikenne Tampereella service. It is important that the information is provided in real-time and updated often enough, especially during peak periods. Internet-pages also provide historical data about past traffic volumes, so users have the possibility to predict future traffic situations and to adapt their behaviour. In this case, the information is hoped to have some kind of effect on the travellers' route choices or timing. Users were asked if the service had succeeded in this and 45% said that the effect of information to route choice and timing is significant. On the other hand, some travellers said that there are not really alternative route choices in Tampere area, so the effectiveness of the information may mostly concentrate on the timing effect. (Laakso et al. 2006.)

Less important factors in this service are uniqueness, validity and cost. The information gained from the Liikenne Tampereella service is not very unique. Although, user can register and get profiled information, everyone can make the same choices and thus get the same information. However, in this case, the service provider has the possibility to develop the system further and thereby provide unique information according to the user's profile. In this case, the information is undoubtedly valid, unambiguous and objective making the discussion of this attribute unnecessary. Information is provided free of charge, but users still need to pay Internet or wap-service fees.

### 3.3.2.2 Valuator

Number of different valutors in the Liikenne Tampereella service is quite small. The user is the one who gets the most significant benefits at the moment.

The users' expectations and goals are related to avoiding congestion and getting to the destination as fast as possible. Real-time information about traffic conditions is easily accessible and available and the possibility to profile acquired information increases the information value further. As mentioned earlier in this study, socio-demographic factors

also affect the valuation of the information. In this case, users are mostly predefined to be commuters travelling with private cars. This means that they are possibly quite wealthy and busy and they have some resources (e.g. time, money) to lose. From this we can conclude that the value of information is quite high, when it is really needed.

Tampere is the third largest city in Finland. There are over 204 000 citizens of which 51% are of working age. The number of private cars is about 81 600 (2004) and the of traffic accidents per year is 1392 (2004). (Tampere taskussa 2005.) The goals of the society are related to reducing congestion and improving traffic flow at certain times. At the moment, the provided information is not as valuable to society as it could be. The information does not have such an impact on users' behaviour that it would substantially affect the general fluency of traffic. According to some users, there are no real possibilities for choosing other routes, thus the timing of travel is the only significant change in user behaviour.

The data used by the Liikenne Tampereella service is mostly produced for other purposes. As a result, the production and maintenance costs are very low, and the service provider can hope earn profit easily. The information value can be easily defined from the expenses of providing the information. If, however, the service is developed further to provide more versatile information, the service provider should think of requiring a small service charge for using the service. In this case, the information value is formed from the profit the service provider gets from providing the service.

### **3.3.3 Value of information**

The Liikenne Tampereella information service is similar to Elmi in that the information value can be assessed by looking at user benefits i.e. using the perceived value method. However, the willingness to pay (WTP) and normative value methods are also useful in this case. When choosing the research method the valuator should consider what he/she wants to find out, and from what perspective the information value needs to be determined.

The normative value method is useful, if one needs to find out the effect of the information on user decision-making and behaviour. In the Liikenne Tampereella service this method is useful because, it is important to also assess the impact the information has on the decision maker's actions, or in other words, the chosen departure time and route. The objective is to find out what kind of effect information has on the final decision: what does the decision maker gain when he/she chooses and uses the information in comparison to the initial situation where he/she was without information? This method is used by first specifying the alternative actions carried out

with or without information, and by then comparing the outcomes according to a suitable procedure. When making the final decision the user should choose an action with best expected outcome. This method best applies to situations where the user is making the route or timing decision. The value of information is hidden, thus user is not conscious of the information having a certain value, but only of the difference in the outcomes. An outsider, who is not involved in the decision making process, can also estimate the information value in different action environments, but practical and reliable results are harder to get.

WTP should be used especially if service provider is planning to place a service charge for the users. With the WTP method the service provider can get a realistic estimate of the maximum amount the users are willing to pay for having access to a certain level of information service. This method should be executed carefully, because users are very keen on answering what they think they are expected to answer regardless of their own opinions, and on the other hand they are not usually interested in giving up free services. The willingness to pay can be assessed e.g. with the method presented by Breidert (2006). In this method, the users are presented different service packages with certain information contents and set prices, and asked if they would pay the given price for using the service. By changing the price and asking users about their willingness to pay, the final maximum and minimum values of the information can be found. Other methods can also be used, but one should be careful when setting questions and possible model answers, because users are very aware of their position and the possible effect of their answers. At the moment, service charge for the Liikenne Tampereella service is not topical, but this method should be kept in mind if the situation changes.

The perceived value type of method was used by Liikenne Tampereella to compile a customer questionnaire the company carried out in October 2006. The number of respondents was 132, which is 9% of the registered users. In the questionnaire the quality of the service was assessed by grading different quality attributes on a five step scale from “very good” to “very bad”. Some of the service quality attributes can also be seen as information quality attributes. For example, the usability, accessibility, coverage, volume, accuracy and effectiveness of the service are directly related to the information quality and they are also useful for valuing the information with the perceived value method. The study gave very coherent results of service quality: 75% of the respondents thought that the service usability was good or very good. The service was also seen as accessible, and its technical functionality as good according to 83% of the respondents. The coverage of the service was seen to be quite extensive, although one fourth of the respondents thought that there was still room for improvements. The service covers 52 roads and streets at the moment. It is important that at least the most congested and popular roads are covered, and this is what the Liikenne Tampereella service has done. Information is also accurate or very accurate according to 71% of



respondents. The study shows that the information affects respondents timing of travel substantially and route choice in 45% of the cases and improves time usage in 26% of the cases. (Laakso et al. 2006.)

Although above mentioned study gives some idea on how users value the service, it does not, however, give proper basis for determining the value of information. It only gives the percentage of people, who think information service is fulfilling these quality attributes, but in order to determine the information value, a more precise and thorough investigation of user benefits and their ranking is needed. It is also important to remember that the quality of the service does not directly equate with the information quality, but rather gives some directions on how information quality is perceived.

## **3.4 Railinc**

### **3.4.1 Description of the service**

Steelroads is a product of the Railinc Corporation (USA). Railinc is owned by the Association of American Railroads, which is formed by the seven largest North American railroads and other industry participants. It “maintains extensive industry databases, applications and services that are embedded in industry critical operations and financial systems”. It provides accurate real-time rail data to support railroads, shippers, equipment owners and suppliers for managing and analyzing their rail traffic. (Railinc n.d.) Railinc has over 40 product lines, of which many have several individual products (Davison 2007, pers. comm., 30 March). Examples of services and service packages are TRAIN II, Railcar accounting, Umler/EMIS, Interline Settlement, EDI connection services, RailSight and Steelroads. (Railinc n.d.)

One of the most important service fields of Railinc is track and trace services. “Using Railinc’s Tracking and Tracing products offers you the ability to filter data by waybill parameters, view waybill elements, trip plans, ETA’s and history.” (Railinc 2007c.) These include Legacy services for railroads, and Steelroads, and RailSight for users. (Davison 2007, pers. comm., 30 March.) Steelroads is a service package for tracking and tracing interline shipments; for finding the best routes; for communicating directly with trading partners; and for using industry specific tools. RailSight is an automated system for tracking railcars and intermodal shipments. Both Steelroads and RailSight provide real-time track and trace reports on more than 330 rail carriers in the United States, Canada and Mexico. The main users of these services are shippers, 3PLs, and forwarders, but also railroad companies themselves are active users. (Railinc 2007a, 2007b, RailSight n.d.)

Although, Steelroads consists of several different services, we shall concentrate on its track and trace services. Track and trace service gives possibility to track and trace shipments on more than 330 railroads in the US, Canada, and Mexico, 24 hours a day, and 7 days a week. It provides, for example, the possibility to trace multiple shipments, to track railcars and intermodal equipment, to maintain visibility in the supply chain with dynamic estimated times of arrival (ETAs), and to check car status. Over 7 million events are recorded daily, and because the information is retrieved directly from the railroads all across North America it is the most reliable and complete service on the market. The equipment trace function allows the user to schedule traces to run automatically, and receive car location messages (CLMs) and ETAs. The parameter trace, on the other hand, allows access to rail shipments by using multiple waybill parameters; enables the customization of reports; allows access to industry reference databases; permits the viewing of waybill elements, trip plans and history; and provides the possibility to automate report delivery. The parameter Trace is especially useful for carload and intermodal shippers, consignees, and other waybill parties. The different output formats include file transfer protocol (FTP), email, fax and web browser (Figure 16). The shipping instructions are a service for submitting bills of lading, viewing, and tracking the status of shipment.

RailSight provides real-time shipment and equipment location information from a single source. Users do not have to request for information, but system produces rail event reports of specified equipments as soon as they have occurred, thus enabling the users to react quickly to unforeseen occurrences. CLMs and ETAs are available to users within minutes of being reported to Railinc. RailSight gives basic equipment tracing data; summarizes all activity to date regardless of the trip cycle stage the shipments are at; and the waybill triggered reporting will add equipment to the user's fleet as soon as the waybill is received. Tracking information gives user money and time savings, reduces uncertainty, increases visibility and creates possibilities for managing inventory, allocating assets and serving customers. The information provided by RailSight can be accessed in several formats including All National Industrial Transportation League (NITL) standard CLM formats, EDI 214 and 322 report formats and XML formats. (Railinc 2007d, RailSight n.d.)



Figure 16. Front page of Steelroads Web Applications ([www.steelroads.com](http://www.steelroads.com)).

## 3.4.2 Characteristics

### 3.4.2.1 Information attributes

For users, especially accessibility, availability and timeliness, are important features of track and trace services. Steelroads and RailSight both provide a wide set of information accessible from one single source. Users do not have to use too much time for hunting down shipments, and RailSight even delivers information straight to users' data system. The information can be received in several different output formats, 24 hour a day, and 365 days a year which means that information is very accessible. The track and trace services provide near real-time data of shipments, which also makes timeliness an important attribute. RailSight provides information within minutes after it is reported to Railinc. Tracing information is quite worthless if it is received when shipment is already at its destination, and cause additional expenses if the shipment is lost, or jammed, and not moving. Railinc is widely known and highly regarded as a service provider, and we can assume that its reputation and reliability does not need to be questioned. The systems' coverage is over 460 rail carriers in the US, Canada and Mexico, which makes it the largest single source of rail transport information service (Railinc 2007).

The most important content factors are accuracy and relevance. RailSight takes care that users are not overwhelmed by irrelevant details, but thank to customization users' only receive relevant information (RailSight n.d.). Information containing errors or needless facts is useless to user and of no value. Completeness is also is also worth consideration, because it is fairly obvious that if there is a gap in the information, its value decreases rapidly.

Other attributes still to consider are validity, effectiveness, and cost. Information needs to be unambiguous or it might cause misunderstandings and loss of resources. Track and trace information does not have actual effectiveness, because at this point the user can not really affect the progress of the shipments. In case some problems occur, the user can however interfere, and correct the situation as soon as possible. When considering information value from users' point of view, the cost does not need to be considered in many cases, because the railroads provide the service free of charge to shippers and consignees they approve. Others use the service on a fee-paid basis. Shippers and consignees, however, pay indirectly for the information when buying transport services from the railroads.

#### 3.4.2.2 Valuator

In this case, it is easy to separate the parties involved in the information distribution chain. Railways are the producers, financiers, and users of the information. Railinc gathers information and offers it to customers (railways) in exchange for money. Railways further distribute the information to users, which can be listed under shippers, companies with own logistics operation, 3PLs and transport companies.

The information value for end user is basically formed by comparing the goals and expectations businesses have on information utility and benefits. Users want to manage their inventory, monitor shipments, optimize supply chain, and so on. Benefits are formed by acquiring and using information of a good quality (e.g. timely, relevant) which can be used to make valuable decisions. With track and trace information the end users can save as much as \$10 000 or even more (Virintie 2004) without paying anything directly themselves. This service system is very beneficial and valuable to the end users, in almost all cases.

Railinc sends over 100 million pieces of information through Steelroads and RailSight every month (Davison 2007, pers. comm., 30 March). The tens of thousands of registered users' benefit from the versatile information services Railinc provides. Railinc is not, however, a very good example of a true for-profit private operator, because it does not maximize its profit, and nor does it usually charge end users for using the service (Virintie 2004). Many end users are not even willing to pay for the

information, although some shippers and consignees, and all third parties are in fact paying for using the service.

This system and its value chain are also different in the fact that the large railroads are at the same time the producers, financiers, main customers and also users of the information service. Railroads give free data to Railinc, and pays for it after revision and processing. According to Railroads the system is profitable because it creates so many operative and customer service benefits, and also directs these benefits to the users. Track and trace information helps management and makes it possible to achieve the highest possible utilization of wagon assets (Davison 2007, pers. comm., 30 March). Therefore, the expenses of buying the services; the benefits of customers and end users; and the customer willingness to pay, need to be considered when valuating the information.

For society, the value of track and trace information is quite small. Society can benefit from the system only in indirectly by e.g. more active business life. The system's overall effect on society is really hard to discuss thoroughly in this case, and thus it is left outside conversation.

### **3.4.3 Value of information**

One method for approaching the information value of track and trace services is the economic approach. When using this method, one needs to consider, what kind of effect information has on the end user's revenue and how much the user can benefit from using the information? What would the situation be if the user could not use the information and how large would the monetary loss be? Information usage saves resources, e.g. time, when all the information can be found from one place and the movement of shipments can be followed and their arrival secured at the right time.

Can the users also save money by using the service? If shippers track, e.g. 500 shipments per month, the savings could be more than \$10 000 annually (Virintie 2004). This number is actually quite close to the value of the information, because the end users are not paying for using the service, and the annual savings show directly how much better off the users are with the information than without it. This follows the logic presented by Williamson (1982), Hilton (1979), and Lawrence (1999) that information value is the difference between the maximum expected payoff with information and without information.

For the service provider, the information value can be looked at directly as the difference between income and expenses i.e. annual revenue. Because the railroads

provide the data used in providing the information for free, the expenses only consists of only administrative and maintenance costs. The annual revenue of Steelroads and RailSight is not, however, very easy to calculate, because the collected data is used for several different services (not just Steelroads or RailSight), and the income is difficult to divide between the different products. In 2002, Railinc generated about \$50 million in revenue (Virintie 2004) of which a reasonable part comes from track and trace services. Because financial statements and other material is not public, the value of the information cannot be stated explicitly here, but value of the track and trace information can be defined, when their share of the annual revenue is known.

Another way of formulating the information value is by studying the customers (railroads) willingness to pay for the information. In this method, a carefully formed questionnaire should be presented to the railroads, and their willingness to pay for different kinds of information should be investigated. This way, the minimum and maximum amount the customers are willing to pay for certain information package is determined. This should be done for information packages with different contents to get an extensive picture of the customers' overall willingness to pay. One should, however, be careful with this method, as mentioned in Chapter 2.3.

The third possible method for defining the information value is to make qualitative assessments with e.g. AHP method. In the AHP method, different information quality attributes are weighted with the by the customers and end users. As many valuator as possible should be used, so that the valuation is not just the opinion of a customer, but a reliable estimation of the most significant quality attributes. First, all the information quality attributes are defined, and the most significant ones addressed in advance. After this, two attributes are placed at the different ends of an assessment line, and customers and end users are asked to determine their reciprocal significance. These pair-wise comparisons should be made at least with all significant attributes, which were determined beforehand. These prioritizations do not directly tell the value of the information, but they give a good picture of what attributes need more attention, and what should be improved to make the information value as high as possible.

### **3.5 Cross case analysis**

As the study shows, information value can be approached from several different perspectives, and many different viewpoints need to be considered. Therefore, there are a few things which need to be discussed, before going deeper into the developed valuation framework. First of all, one should define, what type of information in question, and from whose perspective it is valuated. This is important, because the valuator always has his/her own characteristics and emphasises certain things, these

form the basis of the study. They, in addition to information characteristics, give direction to which valuation method should be used in each case. It is also important to know, the type of service or system through which the information is delivered, because it tells a lot about the information, the information attributes and the whole value chain through which the information travels. One should also find out, if the assessment is made before or after information acquisition, because this also affects the way the information value is determined.

When examining the case studies it should be born in mind that each service provides a different type of information for different target groups. These are summed up in Table 9. Elmi and Liikenne Tampereella should be evaluated mainly from the user perspective, because they are very user centred, and the main benefits are directed to users. Also, the society point of view should be considered, because changes in travel and traffic behaviour can also benefit the society at large. In the case of Elmi company profitability should also be considered, but this is not as important for the Liikenne Tampereella service, because the information it utilises, is used for other purposes as well, and the overall expenses are very low. In the case of Railinc, the line between user and firm is blurred. The railroads are the producers of the information, but they also buy and use the revised information from the service provider. Railroads also provides information its customers, who are the end users of the information. The information value should be considered from service provider's and end user's points of view. The society's benefits are so indistinct that they are left outside conversation.

*Table 9. Information types and target groups of case services.*

	Elmi	Liikenne Tampereella	Railinc
Information type	Real-time information about true bus arrival times.	Real-time information about traffic situations in the Tampere area.	Real-time track and trace information about shipments.
Target group	Elmi-service is directed to public transport users in the Espoo-city area.	Liikenne Tampereella service is directed to travellers in the Tampere area.	Track and trace information is directed mainly to shippers, 3PLs, other logistics operators, and transport companies.

The process of defining information value should start with looking at the information quality attributes framework (Table 5). This framework gives the valuator a new way of looking at information: he/she can dissect the information quality attributes in small pieces and weight relevant attributes. This way, he/she can see what attributes are the most important ones in the case at hand, and what are the relationships between the different attributes. The case studies are covered in this way in following Table 10,

where information attributes are listed on the vertical axis and the cases on the horizontal axes. The information quality components are weighted on the basis of the discussion of Chapters 3.2, 3.3 and 3.4. The weights are suggestive, but they show, which attributes require special attention when the value of information is considered in each case.

*Table 10. Information attributes weighted in each case (- = no need to consider, + = minor importance, ++ = relevant, +++ = very important).*

Attribute	Component	Elmi	LiikenneTampereella	Steelroads
Accessibility	mode & media	++	+++	+++
	traceability	-	+	+
	service reliability	+++	++	++
	service reputation	-	-	+
Contents	accuracy	+++	++	+++
	uniqueness	-	+	-
	relevance	+++	+++	++
	completeness	+++	++	+
Availability	coverage	++	+++	+++
	volume	+++	+++	+++
	consistency	++	++	++
Timeliness	real-time	+++	+++	+++
	history	-	+	-
Validity	unambiguous	++	+	+
	objectivity	-	-	+
Effectiveness	route choice	++	++	-
	mode choice	++		-
Cost		-	-	+

Everyone can assess information quality attributes if they know the assessed information well enough. It should be noted however, that the result highly dependent on the evaluator and the way he/she values things in general. This dependence can be decreased if several people make the assessment and final coefficients and points are the mean values of different assessments. This way the gained result is more reliable and valid.

From the assessed information quality attributes, one can also determine, which attributes are most important ones, and which need more attention in future development. This method shows, what aspects of quality should be improved to increase the value of the information. By improving information quality it is possible to



approach perfect information, and more valuable decisions and outcomes. It is not, however, reasonable to try to reach full 100% quality, because the marginal cost of improvement increases rapidly when getting closer to perfect information.

The above mentioned valuation is not however enough in most cases, but in order to define the value of information one need to conduct a more thorough and versatile discussion. After weighting information quality attributes, one should compare the table to the assessment methods (Table 6), and determine what approach would best suit the current case. The weighted attributes do not always match, and sometimes there are several possible options to choose from. This is why common sense should always be used when trying to find the optimal assessment approach. The information under assessment and the information service value chain should be scrutinized carefully, and approach method chosen should be the one thought to yield the best solution in each case.

In model cases, the information assessment methods were easy to find. In the Elmi-case, the Perceived value method was most practical one, because service is user centred to a very large degree, and method in question gives a good picture of user values and valuation methods, what is valuable to users, and how the service fulfils their needs. For the Liikenne Tampereella service WTP, Normative and Perceived value -methods can be applied. The Normative value method defines the information value by finding out what kind of effect the information has on the final decision: how user is better off with the information than without it? WTP is also useful, if the service provider wants to know how much the users are willing to pay for the information or certain information packages. The perceived value method can be used for same reasons as in Elmi case. Actually, both cases have already been researched using a perceived value type of method. This is a very easy and traditional method, and therefore it is not surprising that it has already been used. This method perhaps gives the best solutions when evaluating the information value from the user perspective for this kind of services. In the Steelroads case, qualitative assessment (AHP method) appears to be a possible solution, but the economic approach is more important, because it is reasonable to make the assessment from firm point of view. Information value can then be seen as the annual revenue from providing certain kinds of information services, because it shows the benefit (monetary in this case) the valuator receives from information.

As we can see, different types of information should be evaluated with different methods. In Table 14 the assessment methods and the information provided by different travel information services are placed against each other. The most useful assessment methods in each case are marked with an “x” and the possible methods with an “x” in parentheses. It should be noted that the given framework is only suggestive one and it depends greatly on the information assessed and the situation at hand. As a conclusion,

it should be said that one should not depend blindly on the results of assessment, but see them more as guidelines.

*Table 11. Framework for travel information value assessment.*

	weight coefficient (0–3)	points (1–5)	total
accessibility	2	5	2*5=10
timeliness	3	4	3*4=12
cost	1	2	1*2=2
			24 (/ 33) points

Same information value assessment approaches and methods can be used for many travel information services. Perceived value and WTP methods are suitable in almost all cases. Many travel information services are really user centred and information value is easiest to determine from the user perspective and with help of the users. This is why, these two methods give good and realistic results. When considering freight services, perceived value is not a very good method, because there is rarely only one single party, from whose perspective the valuation can be made. Usually the information covers several truckers, shippers and for example 3PL's with very different expectations, thus making this kind of valuation quite difficult. WTP is not useful in cases where information is provided free of charge, because travellers are rarely willing to pay for something they can get for free.

Normative value is useful in cases where the decision maker has time to compare different alternatives and choose the best option. Many times travel information is received just before the decision has to be made, thus leaving the decision-maker with only a short time to consider which option is the best. Because of this, the decisions might be wrong, and cause negative value of information. The normative value method is therefore especially useful in evaluating real-time journey time prediction information; Internet based services; multimodal interfaces; telephone information services; and in-vehicle information if the information is received before-trip.

The realistic value approach can be used in situations where the same information can be received in different ways, and if the outcomes of using the different information can be compared. For roadside and telephone information there are usually other options for acquiring the same information, thus making the usage of this assessment method possible. For in-vehicle, Internet, and multimodal information this method is only rarely useful, because usually only one of these methods is available, and therefore they cannot be compared to any other source of information.

Quantitative, economic and qualitative methods are least useful in assessing travel information. The quantitative method is not really useful in any of these cases, because the information quantity does not really tell much about the real value of information, but only the quantity sent and received. The economic value is important, if the service is liable to a charge and the firm is providing the service to make a profit. This goes for especially freight services, and usually to multimodal interfaces as well, because roadside, telephone, in-vehicle and Internet information are usually provided free of charge and funded in other ways. The qualitative method is useful if the valuator wants to value information according to its quality. This method should be used in cases where the information quality can change dramatically and affect decisions and outcomes of activity. For real-time journey time prediction, roadside and telephone information, this method is hard to adapt, but for other information types it might be useful.

## 4. Conclusions

### 4.1 Contribution of the study

Information value has mainly been studied in economics and information sciences. The value of transport information has not however received much attention until recently. The aim of this study is to shed light on this field by investigating whether a method for determining the value of transport information can be found and how this could be done.

The subject is approached by finding out what characteristics transport information has, and what information value assessment methods are useful in this area. Information quality attributes are identified and listed, and a framework is created to get a more comprehensive picture of them. The framework consists of seven attributes (accessibility, contents, availability, timeliness, validity, effectiveness and cost) divided by number of components. The valuator perspectives – user, firm and society – are identified early on in the research and the value chain of travel information services illustrations is developed to provide a clearer picture of how the information and its quality changes, and how the impact of the information also changes at different stages of the value chain. During the literature research several different assessment approaches and methods were identified out of which seven were considered suitable for valuating transport information. The first three approach information value by looking at 1) the value of the decision, 2) the value of outcome and 3) the perceived value. The last four assess information by considering 4) the users' willingness to pay, 5) quantity, 6) the difference between maximum expected payoff with and without information, and 7) qualitative assessment. All these approaches and methods are presented in detail, and they are linked to the information quality attributes by weighting what attributes are important to each assessment method. This helps valuers choose the right assessment method when quality attributes are weighted.

Finally, the subject of information value is approached a practical angle and the theoretical framework put into use in three case studies of information services. The cases represent three different information types common to the field of transport telematics to give a comprehensive picture of transport information services and to provide a good background for creating an assessment framework. Elmi provides real-time information about true bus arrival times; Liikenne Tampereella gives real-time information about the traffic situation in the Tampere city area; and Railinc real-time track and trace information on shipments. The cases were approached on the basis of information gained from the theoretical discussion conducted earlier by defining what information value characteristics the information has and what are the best methods for assessing the information in question. The chosen assessment methods were quite easily

found for each case, and although there was not enough information for defining the final monetary value of information, the procedure for doing this was discovered.

By following the logic of deductive reasoning theoretical conclusions and new knowledge gained from case studies were combined and a framework for information value assessment was created. This framework can be used as guidance, when trying to decide how information should be approached. The framework tells what characteristics should be considered and how they should be treated. It reminds valuator of the pitfalls that might be encountered, and how they can be avoided. The framework also includes a table which shows which of the above mentioned assessment methods are most useful in assessing different types of transport information. The research provides information on what kinds of things the valuator should take notice of and what characteristics should be weighted when assessing information. This research and the created framework offer possibilities for improving the quality of information, to increase gained benefits, to improve information value and to improve business operations.

The framework is developed from transport information service perspective, and it discusses the characteristics of information provided by this service sector thoroughly, and the created framework is best suited for this type of information. However, the framework can also be used for more general purposes for example as a basis for more in depth investigation, or for forming interview questions for information value assessment. It could be possible to develop framework further and also apply it to other service sectors, but this consideration is not included in this discussion.

## **4.2 Reliability and validity**

Reliability “concerns the extent to which an experiment, test, or any measuring procedure yields the same result on repeated trials”. There is, however, always at least a small chance of error, and this is why also a tendency towards consistency is usually referred to as reliability. Validity stands for the extent where measuring instrument measures what it is intended to measure. “– – validity concerns the crucial relationship between concept and indicator.” (Carmines & Zeller 1979.) Validity can further be divided into external and internal validity. The first stands for data, which can be generalized beyond the research project and the latter for the effects measured with dependent variables are caused by some independent variable. (Dane 1990.)

In this research, information value was first approached by literature research. It resulted with two things: firstly, a framework for defining and weighting information quality attributes was created, and secondly, the weighting of different quality attributes for different value assessment methods was defined. These were then used in three case

studies, which provided different kinds of transport information. In general, case information can be considered reliable and valid, because information is acquired from and revised by a trustworthy source. Finally, a framework for defining information value was created with the help of literature research and case studies. This framework is based on profound review of existing methods and cases, and it provides a good basis for valuating transport information services. The valuation methods and the whole research process are defined in detail, and the procedure can be repeated if needed. One should however notice that the valuation process and its results depend highly on three things: the assessment environment, the information under assessment and the valuator. Weighting and grading of quality of attributes, the chosen assessment method(s) and the final results thus vary without doubt from one assessment to another, even if the valuator is assessing the same information. The more complex and the more versatile the information under assessment is, the more complicated and generalized the assessments will be. The created value assessment framework can without a doubt also be adapted for other purposes. The framework can be used as a basis for deeper and more detailed investigation of value or for assessing other types of information, which attest the external validity of the research. However, in addition to being creative, the valuator should also be careful in adopting the framework so that everything is adapted correctly.

In previous studies data, information, information systems, and information services are often confused, and instead of measuring information value they have often measured the value of the information service or the information system. This is understandable, because often these valuations are easier to make and understand. When creating this framework this risk of confusion has been kept in mind. By defining and using terminology coherently, and by creating assessment methods particularly for transport information, this risk has been reduced. However, the framework might also be useful for assessing the value of information systems or services, if it is modified properly.

### **4.3 Further research needs**

The presented framework includes seven different assessment methods. Some of them are more useful than others, and when assessing different types of information not all of them yield satisfactory results. There are, however, approaches needing further research. One of them is the real option theory (see e.g. Trigeorgis 1993, McKenna 2005). It is an option theory applied to evaluating real investments, and to give management the possibility to value the flexibility of their decision-making. The real options given are for example the possibility to delay investments, to make further investments, and to discard investments. (Hellsten 2001.) The real-investments can be substantial or unsubstantial long-term production factors (Neilimo & Uusi-Rauva 2002). In some

cases, the information can be seen as a real-investment, which needs to be changed or delayed on the basis of the changing market situation.

In the future, it would be interesting to apply the framework and the assessment methods in practice. The assessment of different types of information would provide more information about the usability of this method, and repeated assessments of same information would tell if the results are comparable and whether the development of information is visible. Because information value is easier to define on the markets, it would be wise to create, for example, a question framework to facilitate this task. This set of simple questions could help the valuator to pay attention to the right things and determine information values. The questions could differ according to the information type, the valuator, and objectives of the study. One interesting field of study would also be creating some kind of formula where the different information value characteristics are weighted and bonded with mathematical calculations.

This research concentrates on assessment of transport information. However, the world is full of different types of information and information services, and it would be unwise not to widen the view. One fruitful field of research is, thus to develop and apply the created framework to the valuation of different information. Are quality attributes possibly different? How does value chain change? What assessment methods are useful? How can information value be defined?

## Acknowledgements

First, I want to express my gratitude to two people who made this research project possible. Dr. Pekka Leviäkangas, VTT, gave his constant help, support, and encouragement, so that I did not have to struggle alone with the challenging subject of the research. Prof. Harri Haapasalo, from Department of Industrial Engineering and Management of University of Oulu, gave me both ideas and support during the whole research process. I want to thank you both for believing in me.

I also want to thank Risto Kulmala, Raine Hautala and Pirkko Rämä from VTT for helping me and giving me advice, new ideas and constructive criticism. Without you, many important points of view would not have been considered. I also want to send my gratitude to Mika Kulmala from City of Tampere and Treadwell Davison from Railinc who gave me important information relating to the case studies and Anna-Maija Juuso for checking my English grammar and vocabulary.

Lastly I want to thank my family and friends. My mother and father, without your constant love and support, ideas, and time I could not have got this far. I want to thank my friends for taking my mind off the work once in a while, and for giving me something else to think about. Last, but definitely not least, I want to thank you, Markku, for being there for me at all times and for not letting me to worry too much. You mean the world to me.

Maila Herrala, Oulu, May 2007



## References

Adar, Z., Ahituv, N. & Berman, O. 1985, "Value of an Information System for Service Networks", *Computers & Operations Research*, Vol. 12, No. 1, pp. 71–85.

Ahituv, N. 1989, "Assessing the value of information. Problems and approaches", *Proceedings of the Tenth International Conference on Information Systems*, Dec 4–6 1989, ACM, New York, NY, USA, Boston, MA, USA, 315 p.

Ahituv, N., Munro, M.C. & Wand, Y. 1981, "The value of information in information analysis", *Information and Management*, Vol. 4, No. 3, pp. 143–150.

Anderson, I., Neugebauer, J., Ferré, J., Kulmala, R., O'Connor, L., Schwab, N., Thomas, V.R. & Winder, A. 2006. *Data Quality Aspects in Euroregional Projects*, Tempo programme MIP 2005, unpublished.

Bates, J., Polak, J., Jones, P. & Cook, A. 2001/0, "The valuation of reliability for personal travel", *Transportation Research, Part E: Logistics and Transportation Review*, Vol. 37, No. 2–3, pp. 191–229.

Bentham, J. 2000, *An introduction to the principles of morals and legislation*, Batoche, Kitchener, Ont.

Breidert, C. 2006, *Estimation of Willingness-to-Pay: Theory, Measurement, Application*, Deutscher Universitäts-Verlag, Wiesbaden.

Brownstone, D. & Small, K.A. 2005/5, "Valuing time and reliability: assessing the evidence from road pricing demonstrations", *Transportation Research, Part A: Policy and Practice*, Vol. 39, No. 4, pp. 279–293.

Carmines, E.G. & Zeller, R.A. 1979, *Reliability and validity assessment*, Sage Publications, USA.

Centrico n.d., *Variable Message Sign*, [Downloadable pdf-document],  
<<http://www.centrico.ten-t.com/documents/VMSDefinitie.pdf>> (Read 18.1.2007)

Chorus, C., Arentze, T., Molin, E. & Timmermans, H.J.P. 2005, "Value of travel information: Theoretical framework and numerical examples", *Transportation Research Record*, No. 1926, pp. 142–151.

- City of Espoo Pocket Statistics 2006, [Downloadable pdf-document],  
<<http://www.espoo.fi/binary.asp?path=1;28;11894;1033;1042;43708;43709;1044&field=FileAttachment>> (Read 28.3.2007)
- Copeland, E. & Friedman, D. 1992, “The Market Value of Information: Some Experimental Results”, *The Journal of Business*, Vol. 65, No. 2, pp. 241–266.
- Cykana, P., Paul, A. & Stern, M. 1996, “DoD Guidelines on Data Quality Management”, *Proceedings of the 1996 International Conference on Information Quality (MIT IQ Conference)*, ed. R.Y. Wang, Massachusetts Institute of Technology, 154 p.
- Dane, F. 1990, *Research methods*, Brooks/Cole, USA.
- DeSerpa, A.C. 1971, “A Theory of the Economics of Time”, *The Economic Journal*, Vol. 81, No. 324, pp. 828–846.
- Dodd, S.A. 1951, “On Classifying Human Values: A Step In Predictioning Human Valuing”, *American Sociological Review*, Vol. 16, pp. 645–653.
- Dué, R.T. 1997, “The value of information”, *Information Strategy: The Executive’s Journal*, Vol. 13, No. 2, pp. 36–41.
- Emmerink, R.H.M., Nijkamp, P., Rietveld, P. & van Ommeren, J.N. 1996, “Variable message signs and radio traffic information: an integrated empirical analysis of drivers’ route choice behaviour”, *Transportation Research, Part A: Policy and practice*, Vol. 30, No. 2, pp. 135–153.
- Encyclopædia Britannica 2007, *Encyclopædia Britannica online*, [WWW-document], <<http://www.britannica.com/>> (Read 23.3.2007)
- Engelson, L. 2003, “On dynamics of traffic queues in a road network with route choice based on real time traffic information”, *Transportation Research, Part C: Emerging Technologies*, Vol. 11C, No. 2, pp. 161–183.
- Feltham, G.A. 1968, “The Value of Information”, *The Accounting Review*, Vol. 43, No. 4, pp. 684–696.
- FHWA n.d. (Federal Highway Administration), *Managing demand through travel information services*, [WWW-document], <[http://ops.fhwa.dot.gov/publications/manag\\_demand\\_tis/travelinfo.htm](http://ops.fhwa.dot.gov/publications/manag_demand_tis/travelinfo.htm)> (Read 22.2.2007)

Fisher, I. 1968, Is “Utility” the Most Suitable Term for the Concept It Is Used to Denote? In: Page, A.N. 1968, *Utility theory: a book of readings*, John Wiley, New York. Pp. 49–51.

FIST 1998, *Liikenteen ja matkailun informaatio*, Visio 2005, Edita, Espoo.

Freiden, J., Goldsmith, R., Takacs, S. & Hofacker, C. 1998, “Information as a product: not goods, not services”, *Marketing Intelligence & Planning*, Vol. 16, No. 3, pp. 210–220.

Golob, T.F. & Regan, A.C. 2005, “Trucking industry preferences for traveler information for drivers using wireless Internet-enabled devices”, *Transportation Research, Part C: Emerging Technologies*, Vol. 13, No. 3, pp. 235–250.

Gunn, H. 2001/0, “Spatial and temporal transferability of relationships between travel demand, trip cost and travel time”, *Transportation Research, Part E: Logistics and Transportation Review*, Vol. 37, No. 2–3, pp. 163–189.

HEATCO n.d., *National values for transport evaluations*, unpublished.

Hellsten, I. 2001, *Reaaliopioiteorian sovellettavuus tuotekehitysinvestointeihin liittyvässä päätöksenteossa*, (Applying real option theory to the evaluation and selection of R&D projects), Master’s Thesis, Lappeenranta University of Technology, [downloadable pdf-document], <[http://www.tbrc.fi/pubfile/TBRC\\_10038.pdf](http://www.tbrc.fi/pubfile/TBRC_10038.pdf)> (Read 4.4.2007)

Hilton, R.W. 1979, “The Determinants of Cost Information Value: An Illustrative Analysis”, *Journal of Accounting Research*, Vol. 17, No. 2, pp. 411–435.

Hilton, R.W. 1981, “The determinants of information value: synthesizing some general results”, *Management Science*, Vol. 27, No. 1, pp. 57–64.

Hirshleifer, J. 1973, “Where Are We in the Theory of Information?”, *The American Economic Review*, Vol. 63, No. 2, pp. 31–39.

ITIS Holdings n.d., *Applications / iTMC™*, [WWW-document], <<http://www.itisholdings.com/itmc.asp>> (Read 19.2.2007)

Iyengar, J.V. 1996, “Information value – an utility approach”, *Journal of Computer Information Systems*, Vol. 37, No. 2, pp. 37–40.

- Jara-Diaz, S.R. 1990, "Consumer's surplus and the value of travel time savings", *Transportation Research, Part B: Methodological*, Vol. 24B, No. 1, pp. 73–77.
- Jiang, M. & Morikawa, T. 2004, "Theoretical analysis on the variation of value of travel time savings", *Transportation Research, Part A: Policy and Practice*, Vol. 38A, No. 8, pp. 551–571.
- Karnes, C.L., Sridharan, S.V. & Kanet, J.J. 1995, "Measuring quality from the consumer's perspective: a methodology and its application", *International Journal of Production Economics*, Vol. 39, No. 3, pp. 215–225.
- Kenyon, S. & Lyons, G. 2003/3, "The value of integrated multimodal traveller information and its potential contribution to modal change", *Transportation Research, Part F: Traffic Psychology and Behaviour*, Vol. 6, No. 1, pp. 1–21.
- Keskinarkaus, J. & Haapasalo, H. 2004, *Liikennetelematiikan toimialamalli – kuvaus liikennetelematiikka-alan toimijoiden rooleista*, Oulun yliopiston tuotantotalouden osaston tutkimusraportteja 1/2004, Oulun yliopisto, Oulu.
- Khattak, A.J., Yim, Y. & Prokopy, L.S. 2003, "Willingness to pay for travel information", *Transportation Research, Part C: Emerging Technologies*, Vol. 11, No. 2, pp. 137–159.
- Killi, M. & Samstad, H. 2002, *Trafikanter verdsetting av informasjon med utgangspunkt i arbeidesreiser (Travellers valuation of traffic information based on work journeys)*, TØI, Oslo.
- Kim, S., Lewis, M.E. & White, C.C. 2005, "Optimal vehicle routing with real-time traffic information", *IEEE Transactions on Intelligent Transportation Systems*, Vol. 6, No. 2, pp. 178–188.
- Kitamura, R., Laidet, L. & Mar, F. 1995, *An Evaluation Study of a Low-Cost, Telephone-Based Traveler Information System*, University of California, Davis.
- Kulmala, R. & Karhumäki, T. 2007. *VIKING Monitoring Guidelines 2006*, unpublished.
- Laakso, J., Ylisiurunen, K., Varjola, M. & Lehtinen, I. 2006, *FCD-menetelmä ajantasaisen liikenneinformaation tuottamisessa, loppuraportti (FCD-method in providing real time traffic information)*, Aino publications 37/2006.

Lam, T.C. & Small, K.A. 2001/0, "The value of time and reliability: measurement from a value pricing experiment", *Transportation Research, Part E: Logistics and Transportation Review*, Vol. 37, No. 2–3, pp. 231–251.

Lawrence, D.B. 1999, *The Economic Value of Information*, Springer, New York.

Lee, K.H. & Hatcher, C.B. 2001, "Willingness to Pay for Information: An Analyst's Guide", *Journal of Consumer Affairs*, Vol. 35, No. 1, p. 120.

Liikennetampereella.fi n.d., Liikenteen tila ja häiriöt (Current traffic conditions), [WWW-document], <<http://www.liikennetampereella.fi>> (Read 13.2.2007)

Lovata, L.M. 1987, "Behavioral Theories Relating to the Design of Information Systems", *MIS Quarterly*, Vol. 11, No. 2, pp. 147–149.

Mackie, P.J., Fowkes, A.S., Wardman, M., Whelan, G., Nellthorp, J. & Bates, J. 2003, Value of travel time savings in the UK: summary report, [WWW-document], <<http://www.dft.gov.uk/pgr/economics/rdg/valueoftraveltimesavingsinth3130>> (Read 5.2.2007)

Margiotta, R. 2002, State of the practice in traffic data quality, White Paper, Federal Highway Administration, USA.

McCaffrey, J. 2005, "The Analytic Hierarchy Process", *MSDN Magazine*, Vol. 20, No. 6, pp. 139–144.

McKenna, P. 2005. Assessing the economic value of software products. [WWW-document], <<http://www-128.ibm.com/developerworks/rational/library/nov05/mckenna/>> (Read 15.3.2007)

Mock, T.J. 1971, "Concepts of Information Value and Accounting", *The Accounting Review*, Vol. 46, No. 4, pp. 765–778.

Mosteller, F. & Noguee, P. 1951, "An Experimental Measurement of Utility", *Journal of Political Economy*, Vol. 59, pp. 371–404.

Mäkinen, J., Molin, P. & Leinonen, J. 2005, Ajantasaisen liikenneinformaation markkinaselvitys (Market Study on Dynamic Traffic Information), ITS Finland publication 3/2005.

Neilimo, K. & Uusi-Rauva, E. 2002, *Johdon laskentatoimi*, Edita, Helsinki.

Nykysuomen sanakirja 1985, WSOY, Porvoo.

Olkkonen, T. 1993, Johdatus teollisuustalouden tutkimustyöhön, Teknillinen korkeakoulu, Espoo.

O'Reilly, Charles A. III 1982, "Variations in Decision Makers' Use of Information Sources: The Impact of Quality and Accessibility of Information", The Academy of Management Journal, Vol. 25, No. 4, pp. 756–771.

Pesonen, H., Laine, T., Bäckström, J., Granberg, M., Vehmas, A. & Niittymäki, J. 2002. Reaaliaikaisen matkustajainformaatiojärjestelmän (ELMI) vaikutusten ja yhteiskuntataloudellisen kannattavuuden arviointi (Assessment of impacts and socio-economical profitability of real-time passenger information system [ELMI]). FITS Publications 7/2002.

Railinc n.d., Railinc "Maximizing Value to the Railroad Industry", [Downloadable pdf-document], <<http://www.railinc.com/docs/Railinc.pdf>> (Read 20.2.2007)

Railinc 2007a, Railinc Launches Powerful Parameter Tracing, [WWW-document], <<http://www.steelroads.org/view.cfm?cnid=314>> (Read 20.2.2007)

Railinc 2007b, Steelroads benefits, [WWW-document], <<http://www.railinc.com/view.cfm?cnid=173>> (Read 21.2.2007)

Railinc 2007c, Tracking & Tracing, [WWW-document], <<http://www.railinc.com/view.cfm?cnid=194>> (Read 30.3.2007)

Railinc 2007d, RailSight, [WWW-document], <<http://www.railinc.com/view.cfm?cnid=64>> (Read 30.3.2007)

RailSight n.d., [Downloadable pdf-document], <<http://www.railinc.com/docs/RailSight.pdf>>, (Read 30.3.2007)

RDS-TMC n.d., [WWW-document], <<http://www.rds-tmc.co.uk>> (Read 19.2.2007)

Repo, A.J. 1989, "The value of information: approaches in economics, accounting, and management science", Journal of the American Society for Information Science, Vol. 40, No. 2, pp. 68–85.

Repo, A.J. 1986, “The dual approach to the value of information: an appraisal of use and exchange values”, *Information Processing & Management*, Vol. 22, No. 5, pp. 373–383.

Rescher, N. 1982, *Introduction to value theory*, University Press of America, Washington.

Saaty, T. 1980, *The Analytic Hierarchy Process*, McGraw-Hill, USA.

Schumpeter, J. 1908–1909, “On the concept of social value”, *Quarterly Journal of Economics*, Vol. 23, pp. 213–232.

Shannon, C.E. 1948, “A Mathematical Theory of Communication”, *The Bell System Technical Journal*, Vol. 27, pp. 379–423, 623–656.

Sheridan, T.B. 1995, “Reflections on information and information value”, *IEEE Transactions on Systems, Man and Cybernetics*, Vol. 25, No. 1, pp. 194–196.

Smith, A. 1999, *The wealth of nations*, ElecBook [E-book EBRARY].

SPECTRUM 2004, *Deliverable D6: Measurement and Treatment of High Level Impacts*, European Commission, Institute for Transport Studies, University of Leeds (ITS), Leeds, [Downloadable pdf-document],  
<<http://www.its.leeds.ac.uk/projects/spectrum/downloads/D6.pdf>> (Read 22.3.2007)

Strong, D.M., Lee, Y.W. & Wang, R.Y. 1997, “Data quality in context”, *Association for Computing Machinery. Communications of the ACM*, Vol. 40, No. 5, p. 103.

Tampere taskussa 2005, [Downloadable pdf-document],  
<<http://www.tampere.fi/tiedostot/58GdZkuRX/TASKU05.pdf>> (Read 28.3.2007)

Taylor, R.S. 1986, *Value-Added Processes in Information Systems*, Ablex Publishing, Norwood, N.J.

Tiehallinto 2005, *Tieliikenteen ajokustannusten yksikköarvot 2005*, Tiehallinto, Helsinki.

TIS EG (Traveller Information Services Expert Group) 2006, *Success stories in Traveller Information Services (TIS): Perspectives for the future*, EU Tempo report.

Toppen, A. & Wunderlich, K. 2003, Travel Time Data Collection for Measurement of Advanced Traveler Information Systems Accuracy, FHWA, U.S. Department of Transportation.

Trigeorgis, L. 1993, "Real options and interaction with financial flexibility", *Financial Management*, Vol. 22, No. 3, p. 202

Turner, S. 2002, State of the practice for traffic data quality, White Paper, Federal Highway Administration, USA.

Virintie, H. 2004, Organization of CroBIT Service Provision, unpublished consultation report for CroBIT (5th FP) project.

Virtanen, N. 2005, Automaattisen hätäviestijärjestelmän vaikutukset onnettomuus-tilanteessa (Impacts of an automatic emergency call system on accident consequences), AINO-julkaisu 14/2005.

VMS n.d., MS4 Series, [Downloadable pdf-document],  
<<http://www.vmslimited.co.uk/ms4.pdf>> (Read 18.1.2007)

Vroom, V.H. 1964, *Work and motivation*, John Wiley, New York.

Väliharju, R., Ylisiurunen, K. & Laakso, J. 2006, ASKEL, Konkreettinen ja taloudellinen askel kaupunkiseudun multimodaalisiin liikennepalveluihin (ASKEL – Tampere Multimodal Services and Innovative Steps towards Commercial Resources), AINO publications 33/2006.

Wand, Y. & Wang, R.Y. 1996, "Anchoring data quality dimensions in ontological foundations", *Association for Computing Machinery. Communications of the ACM*, Vol. 39, No. 11, p. 86.

Wang, R.Y., Storey, V.C. & Firth, C.P. 1995, "A Framework for Analysis of Data Quality Research", *IEEE Transactions on Knowledge and Data Engineering*, Vol. 7, No. 4, pp. 623–640.

Wardman, M. 2001, "A review of British evidence on time and service quality valuations", *Transportation Research, Part E: Logistics and Transportation Review*, Vol. 37, No. 2–3, pp. 107–128.

Wegen, B. & Hoog, R. 1996, "Measuring the economic value of information systems", *Journal of Information Technology*, Vol. 11, pp. 247–260.



Williamson, R.W. 1982, "Presenting Information Economics to Students", *The Accounting Review*, Vol. 57, No. 2, pp. 414–419.

Wolinetz, L.D. 2001, *Why will some individuals pay for travel information when it can be free? Analysis of a Bay Area Travel Survey*, University of North Carolina, Chapel Hill.

Yang, H. & Meng, Q. 2001/12, "Modeling user adoption of advanced traveler information systems: dynamic evolution and stationary equilibrium", *Transportation Research, Part A: Policy and Practice*, Vol. 35, No. 10, pp. 895–912.



## Appendix A: The value of information by Williamson

Williamson (1982) represents a simple set of computations to first attain expected values of sales and cost of prediction error and then expected value of perfect and sample information. For calculations we have a case where manager need to decide between two different actions ( $a_1, a_2$ ) to maximize the profit on the basis of two possible events. Event one ( $e_1$ ) has a demand of 1200 products and doing  $a_1$  gives total profit of 90000 and  $a_2$  84000. Event two ( $e_2$ ) has a demand of 2000 when  $a_1$  gives profit of 130000 and  $a_2$  14000. Initial analysis uses payoff table to calculate expected values of total profit. For the calculations manager estimates that possibility of event 1 is 40% and possibility of event 2 is 60%. The resulting payoff table is shown as Table A1. In this case we can assume that manager will choose action two, because it gives higher profit. (Williamson 1982.)

*Table A1. Payoff table and expected values (adapted from Williamson 1982).*

	Events		
	$e_1$	$e_2$	
probability of events	0,40	0,60	
			Expected value
$a_1$	90 000	130 000	114 000
$a_2$	84 000	140 000	117 600

After this calculation smart manager asks “What if I choose action 2, but the demand will be only 1200?” This is said to be the cost of prediction error which represents the difference between what you could have done and what you expect to and is calculated in the following matter:

When demand is 1200, what is the profit of best alternative?	90 000
When demand is 1200, what are the profits after choosing action 2?	84 000
Cost of prediction error	6 000

Cost of prediction error gives the maximum amount what we would be willing to pay for information that would help us predict future events. In the case of choosing action 2 the cost of prediction error would be 10 000. However, cost of prediction error is not realistic, because it does not take into account the probabilities of various events. Probabilities should be considered and they are taken into account in calculating expected value of perfect information (EVPI). EVPI is the difference between expected

total profit, knowing which event will in fact occur and the expected total profit with current information. (Williamson 1982.)

Expected total profit with perfect information (90 000*0,4+14 000*0,6)	120 000
Expected total profit with current information	117 600
<hr/>	
Expected value of perfect information (EVPI)	2 400

Usually it is not possible to get perfect information, but additional information instead. In this case manager has a possibility to hire a consultant who is right 80% of the time. This means that if consultant gives pessimistic report ( $r_1$ ) the demand will be 1200 in 80% of those instances and with optimistic report ( $r_2$ ) demand will be 2000 in 80% of those instances. With this information we get conditional probabilities of

$$\begin{aligned} P(r_2 | e_2) &= 0,80 & P(r_1 | e_1) &= 0,80 \\ P(r_1 | e_2) &= 0,20 & P(r_2 | e_1) &= 0,20 \end{aligned}$$

Manager still estimates the probabilities of events to be  $P(e_1)=0,4$  and  $P(e_2)=0,6$  and by knowing that

$$P(r_j) = \sum_{i=1}^2 P(r_j | e_i) * P(e_i), \quad (1)$$

we can compute  $P(r_1)=0,44$  and  $P(r_2)=0,56$ . With the help of Bayes' Theorem

$$P(e_i | r_j) = \frac{P(r_j | e_i) * P(e_i)}{P(R_j)} \quad (2)$$

we compute additional conditional probabilities as follows:

$$\begin{aligned} P(e_1 | r_1) &= 0,727 & P(e_1 | r_2) &= 0,143 \\ P(e_2 | r_1) &= 0,273 & P(e_2 | r_2) &= 0,857 \end{aligned}$$

After these calculations we can create new payoff table (Table A2) with additional information and new probabilities.

*Table A2. Expected values with sample information.*

$r_1 =$ pessimistic report		Expected value
$a_1$	$90\,000 \times 0,727 + 130\,000 \times 0,273$	100 920
$a_2$	$84\,000 \times 0,727 + 140\,000 \times 0,273$	99 288
$r_2 =$ optimistic report		Expected value
$a_1$	$90\,000 \times 0,143 + 130\,000 \times 0,857$	124 280
$a_2$	$84\,000 \times 0,143 + 140\,000 \times 0,857$	131 992

Expected value of sample information (EVSI) can now be calculated as a difference between the expected payoff given additional information and the expected payoff with current information. EVSI is thus maximum amount manager should pay for information that is right 80% of the time. (Williamson 1982.)

Expected total profit with additional information ( $100\,920 \times 0,44 + 131\,992 \times 0,56$ )	118 320,32
Expected total profit with current information	117 600,00
Expected value of sample information (EVSI)	720,32



## Appendix B: The value of information by Lawrence

To understand the method Lawrence (1999) use in his information value calculations it is useful to present different dimensions and variables he uses. *Action space*  $A=\{a\}$  includes all the available and practicable actions  $a$ , which can be used to realize decision. *State space*  $X=\{x\}$  is a set of possible outcomes of chosen actions, within  $x$  is a specific state of nature. *Message space*  $Y=\{y\}$  lists all possible messages  $y$  receivable from the information source. *Information structure*  $I = \{Y, p(x,y)\}$  comprises the message space and the joint probability distribution of message and state. (Lawrence 1999.)

Starting point for information evaluation is the *ex-post value of the message*  $y$ . It measures the overall impact of the message on the decision maker's payoff and is the difference between terminal payoff under optimal action  $a_y$  and under prior action  $a_0$  in the realized state  $x$ .

$$v(x, y) = \pi(x, a_y) - \pi(x, a_0) \quad (1)$$

When generalizing this formula we get (5). Here the decision maker gets the message  $y$  and makes the choice  $a_y^u$  (knowing the utility of outcome) when the state  $x_i$  occurs. After the message and the state, decision maker's terminal wealth is  $\omega(w, x_i, a_y^u)$  and without using the message it would have been  $\omega(w, x_i, a_0^u)$  thus ex-post value of a message is

$$\bar{v}^u(x_i, y) = \omega(w, x_i, a_y^u) - \omega(w, x_i, a_0^u) \quad (2)$$

Either of these ex-post values of information does not incorporate the costs of accessing, processing and applying the message, which is why we have to subtract cost  $C$  to gain the *realized incremental gain*

$$G = v(x, y) - C \quad (3)$$

Decision-maker faces also different uncertainties because of the ex-ante nature of decision-making. Actions must be chosen; sources must be evaluated, priced and chosen; and system designed before information need arises. Available options can be evaluated and compared with the *expected value* of relevant objective function, where  $E_x g(x)$  is expected value of a function  $g(x)$  having probability distribution  $p(x)$ .

$$E_x g(x) = \sum_i g(x_i) p(x_i) \quad (4)$$

Maximum expected payoff without the source can be expressed according to this formula as  $E_x \pi(x, a_0)$  and optimal response to the message  $y$  prior to the realization of state variable  $X$  can be expressed as  $E_{x|y} \pi(x, a_y)$ . If we assess also the quantity of every  $y$  that might be received and weight it by its probability  $p(y)$ , we get the marginal probability of receiving the message:  $E_y E_{x|y} \pi(x, a_y)$ . This is the expected payoff prior receiving any message. With information structure  $I$ , the *expected value of information* can be calculated as follows:

$$V(I) = E_y E_{x|y} \pi(x, a_y) - E_x \pi(x, a_0) \quad (5)$$

$V(I)$  is the maximum amount decision maker should pay for incorporating information to decision making to expect to be better off. Expected gain can be easily calculated by  $V(I) - C$  if  $C < V(I)$ . If  $C > V(I)$ , incorporating information is not profitable and decision maker should not access this information source. (Lawrence 1999.)



<p>Author(s) Herrala, Maila</p>		
<p>Title <b>The value of transport information</b></p>		
<p>Abstract Information value has been mostly discussed in business and information economics. Now, due to the fast development of communication technologies, a new interesting field of research has emerged – transport telematics. The objectives of this research were to identify the attributes affecting the value of transport information, and to specify the valuation methods applied. This study also includes discussion on three case studies concerning transport telematics. A further objective was to identify the relevant information attributes and the feasible assessment methods for each case. The study was carried out at VTT Technical Research Centre of Finland with co-funding from Tekes – the Finnish Funding Agency for Technology and Innovation.</p> <p>The first part of the study, a literature survey resulted in a general framework for information value assessment. This framework can be used when evaluating various transport information to analyse which information characteristics need to be taken into account, and which assessment methods should be applied. This framework can be presented in two tables, where the first one identifies the information quality attributes, and the second one attaches these to the appropriate value assessment methods in each case. The second part of the study deepens the first part by applying the general framework to real-life information by studying three transport information service cases on the basis of available data. In each case, the relevant information value characteristics are identified and the appropriate assessment methods specified. The case studies proved that the evaluation framework was useful for evaluating information value.</p> <p>The evaluation framework was created from the perspective of transport information. Hence, it is most suitable for evaluating the value of information provided by the transport service sector. In addition to the theoretical valuation of information, this framework can, however, be used as a basis for deeper and more detailed investigation, and also in research more empirical than the cases studied here. It is also likely, that the framework could be applied to other kinds of information, but in this case the valuator needs to carefully adapt the framework to suit the type of information in question.</p>		
<p>ISBN 978-951-38-6938-0 (soft back ed.) 978-951-38-6939-7 (URL: <a href="http://www.vtt.fi/publications/index.jsp">http://www.vtt.fi/publications/index.jsp</a>)</p>		
<p>Series title and ISSN VTT Tiedotteita – Research Notes 1235-0605 (soft back ed.) 1455-0865 (URL: <a href="http://www.vtt.fi/publications/index.jsp">http://www.vtt.fi/publications/index.jsp</a>)</p>		<p>Project number 4306</p>
<p>Date July 2007</p>	<p>Language English</p>	<p>Pages 87 p. + app. 5 p.</p>
<p>Name of project Evaserve</p>	<p>Commissioned by Tekes – the Finnish Funding Agency for Technology and Innovation, the Finnish Meteorological Institute, Destia, Ministry of Transport and Communications Finland, VTT Technical Research Centre of Finland</p>	
<p>Keywords transport information services, transport telematics, quality assessment, value assessment, value of information, logistics services, information attributes, travel information services, value chains, valuation methods</p>	<p>Publisher VTT Technical Research Centre of Finland P.O. Box 1000, FI-02044 VTT, Finland Phone internat. +358 20 722 4404 Fax +358 20 722 4374</p>	

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