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VTT Technical Research Centre of Finland

Ari Venäläinen and Seppo Saku
Finnish Meteorological Institute

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tel. växel 020 722 111, fax 020 722 4374

VTT Technical Research Centre of Finland, Vuorimiehentie 3, P.O.Box 1000, FI-02044 VTT, Finland
phone int'l. +358 20 722 111, fax +358 20 722 4374

VTT, Kaitoväylä 1, PL 1100, 90571 OULU
puh. vaihde 020 722 111, faksi 020 722 2090

VTT, Kaitoväylä 1, PB 1100, 90571 ULEÅBORG
tel. växel 020 722 111, fax 020 722 2090

VTT Technical Research Centre of Finland, Kaitoväylä 1, P.O. Box 1100, FI-90571 OULU, Finland
phone internat. +358 20 722 111, fax +358 20 722 2090

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Abstract

This research report looks into the benefits of hydrological and meteorological information services in Croatia. The benefits generated by the day-to-day services were investigated by beneficiary sector. Each sector was studied by different researchers. The methods used were multiple: literature reviews and statistics, expert interviews and workshops, and analytical, conceptual and qualitative model building and modeling of expected impacts. Assuming that the annual budget of DHMZ is about 8 million € per year, this study concludes that the services delivered by DHMZ pay themselves back by at least 3-fold each year. Taking into account all the excluded sectors, it is further concluded that the factual ratio is even higher. The results seem to be in line with other research results. By improving the services, especially their deliverance, substantial additional benefits can be generated, hence justifying the investments in the improvement of hydrological and meteorological services.

Preface

This research report looks into the benefits of hydrological and meteorological information services in Croatia. The benefits generated by the services were investigated by beneficiary sector. Each sector was studied by different researchers. This study is a part of a wider research effort seeking methods and approaches to analyse different types of information services (EVASERVE *www.evaserve.fi*). Funding for the research described in this report came from FINNFUND Ltd. (Finnish Fund for Industrial Cooperation Ltd.) and VTT Technical Research Centre of Finland.

The reporting was performed by the following VTT researchers:

Dr Pekka Leviäkangas (editor) – methods, overall reporting, rail transport
MSc Raine Hautala – summary, overall reporting
MSc Jukka Räsänen – methods, aviation
MSc Risto Öörni – road transport
Captain Sanna Sonninen – maritime transport
Dr Martti Hekkanen – construction and facilities
MSc Mikael Ohlström – energy, air quality

The researchers of Finnish Meteorological Institute (FMI) assisted VTT and wrote a section of this report:

MSc Seppo Saku – agriculture
Dr Ari Venäläinen – agriculture.

The Management team of Croatian Hydrological and Meteorological Service (DHMZ) made significant contributions to the study. This group comprised the following key persons:

Director General, MSc Ivan Čačić
Director, Dr Vlasta Tutiš
Director, BSc Nino Radetic
Director, Dr Branka Ivančan-Picek
Director, Dr Krešo Pandžić

along with many other key people from DHMZ. Representatives from Croatian State Directorate for Rescue and Protection, Croatian Motorways and Croatian National Electricity participated in this work and made valuable contributions.

The quality assurance for this report was done by MSc Petri Mononen from VTT.

This report represents the views of independent researchers only, and not those of any participating organization. We thank all our dear colleagues from Croatia, particularly those from DHMZ as well as from Finland – FMI, VTT and Impact Consulting Ltd. – for their contributions and efforts which made this study possible.

VTT Technical Research Centre of Finland, Espoo, December 2007,

Pekka Leviäkangas Raine Hautala

Contents

1. Introduction

1.1 Background

Croatia, like many other European countries, is moving towards joining the European Union. EU will bring new challenges for Croatia. The liberalization of many sectors of the society will take place and also the different functions of the society will face market exposure. Directive on services in the internal market is not explicitly including or excluding the meteorological services, but most likely some meteorological services will be counted as a service to which the directive applies[1].

Another important trend is the explosion of the IT and mobile technologies enabled consumer and corporate information services. This will take place widely, covering all aspects of society and on a global scale.

For a mature service sector, like meteorological and hydrological information service, these trends create challenges and opportunities. On one hand technology enabled service enhancement possibilities and the possibility to “access the free market” and on the other hand the pressure to develop services to meet the increasing demands. Meteorological and hydrological services, weather services to use a layman’s definition, are no exception to the rule. Especially when we consider that the infrastructure to make observations, i.e. to gather data, is already built, the prospects of developing service systems on top of this infrastructure are particularly good. In a way, only a new “architecture layer” is needed to take full advantage of the new technology. As to meteorological sector, Figure 1 illustrates the situation.

Figure 1 relies on two main theories. The first is about information value stating that the value is highly dependent on multiple attributes (cost, reliability, validity, availability, etc.) (see Herrala 2007). The other is the theory of technology management, namely stating that technological entities have certain type of life-cycles (see e.g. Khalil 2000). We can regard a meteorological service organisation as a technological entity comprising many layers which all require different investments with different life cycles. When the observation network is in place and there is an organisation to run the entity, we can assume (and actually witness empirically through our own senses) that the next step is to develop new systems enhancing the utilisation of the existing systems. Thus, the met-organisation is composed of different “layers”, the advancement of which dictate how effective it is in producing and disseminating its services. A layered, service-oriented view to met-organisation in particular is shown in Figure 2.

[1] Directive 2006/123/EC of the European Parliament and of the Council of 12 December 2006 on services in the internal market. Official Journal of European Union, 27.12.2006.

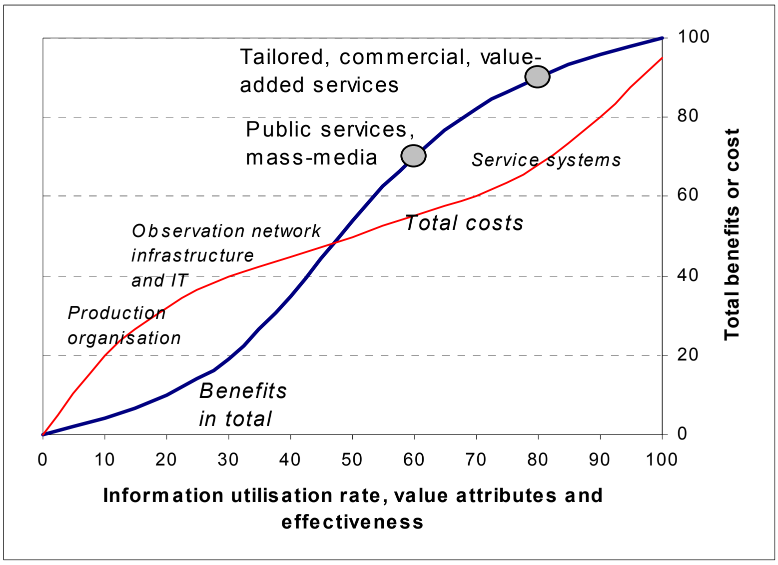


Figure 1. The total costs (red line) accumulate quickly (capital intensive investments) when infrastructure is put in place but later the accumulation slows down (non-physical and semi-physical investments). The benefits (blue line) start to accrue later, when services are penetrating the market, i.e. they are more widely utilised in an efficient manner and start to have measurable impacts.

The important message of Figure 2 is that benefits are generated only when services meet the customers in need. However, the services are not likely to emerge – at least on a wider scale – unless the supporting layers are in order and place. Other implications due to lame or inadequate supporting layers are for example:

- sub-standard and poor quality services
- badly targeted services
- excessive focusing on administrational and organisational issues instead of market orientation
- excessive focusing on supportive work processes leading to market neglectance, lack of focus and overspending
- excessive focusing on physical infrastructure leading to overspending
- low demand of services due to quality deficiences in supporting layers.

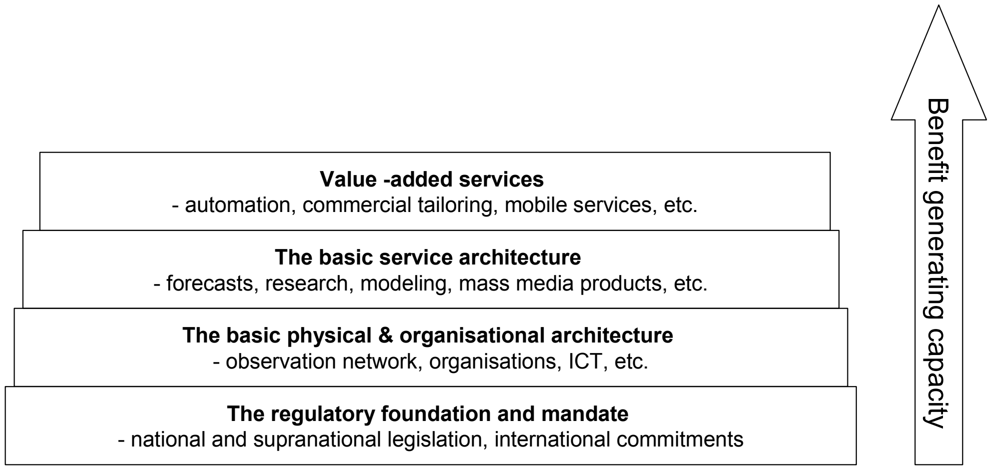


Figure 2. A layered and service-oriented view to a met-service organisation.

1.2 The scope of the study

This study concentrates mainly on three issues:

1. the services currently supplied by DHMZ; mainly based on the discussions between VTT and DHMZ and on documented material provided by DHMZ
2. the customer needs, and the need to enhance and improve the services; these were mainly based on customer-involving workshops that were held in Croatia and Finland
3. the benefits resulted by the services; the assessment of benefits was based on known or assessed impacts of services (see chapter 2); the benefits were valued in monetary terms.

This study is not taking any stands on DHMZ's internal benefits or costs when it comes to hydro-met service production, distribution and use. These issues were dealt with in another report that was an integral part of this study, but reported separately (Leviäkangas et al. 2007). Nor does this study address to the very typical view of damage reduction. Hydrological and meteorological services can reduce damages of exceptional weather phenomena and thus there is a benefit to gain. However, this study focuses on everyday services provided by the institute.

2. The carry-out and the methods

2.1 The carry-out of the study

The carry-out plan of the study is shown in Figure 3. The first step, Present Meteorological Information Services, was carried out through several fact-finding missions[2] by VTT researchers. The costs were also pinned down during those missions. The benefits are reported here in this report. The following step, Needs Analysis, was done by arranging two customer-involving workshops[3], one in Espoo and one in Zagreb. The potential benefits are reported here in this report as well as "The Gap Analysis" (see chapters 5.4 and 5.5). Gap analysis points out the differences between the current services and identified or potential customer needs. The final step, Action Plan 2010, is reported in Leviäkangas et al. (2007).

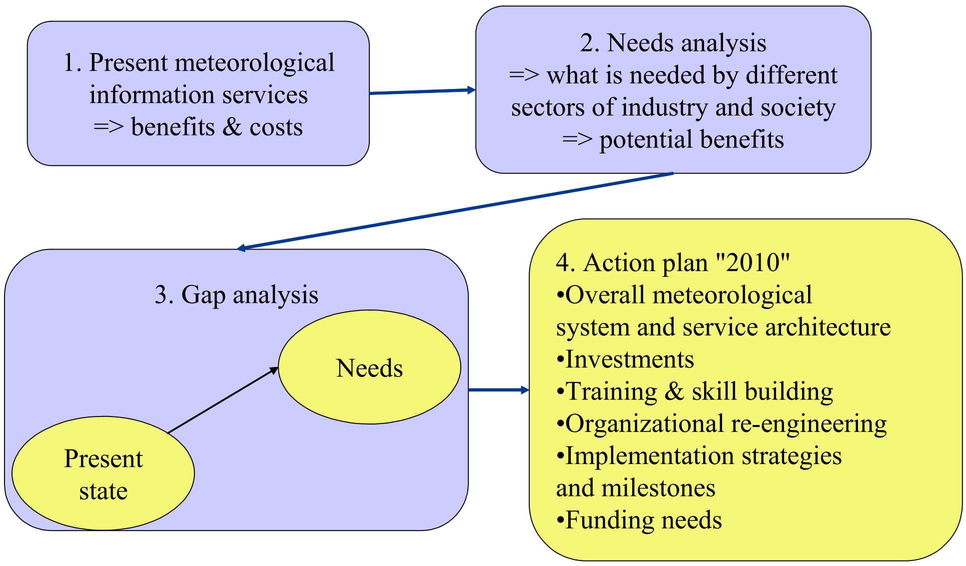


Figure 3. The plan for the analysis of Croatian hydrological and meteorological information services.

2.2 Methods

In this section, the generic methodological approach is given. In each sector-specific analysis a more detailed method description is laid down, but there are common elements for all sector-specific analyses. The methods used in this study are as follows:

[2] Several missions during 2006 and 2007.
[3] 19.–20.6.2006 in Espoo and Helsinki, Finland and 7.–8.11.2006 in Zagreb, Croatia.

- literature reviews and statistics
- expert interviews and workshops
- analytical, conceptual and qualitative model building and modelling of expected impacts.

The international scientific and professional literature was reviewed to the extent allowed by the project's resources. The review served mainly as a basis to construct relevant, but preliminary impact mechanisms. These impact mechanisms were either validated by research teams (two or more researchers making the validation based on their experience) or in expert workshops (as described earlier). Expert workshops were also used in the derivation of impact mechanisms. The models for impact mechanisms are usually not explicit, and in most cases they rely on conceptual notation (i.e. the models are logical chain of events and impacts) or they are purely qualitative (i.e. they are descriptive but neither explicitly nor mathematically formulated).

Figure 4 illustrates the research approach adopted and the dynamics between research phases.

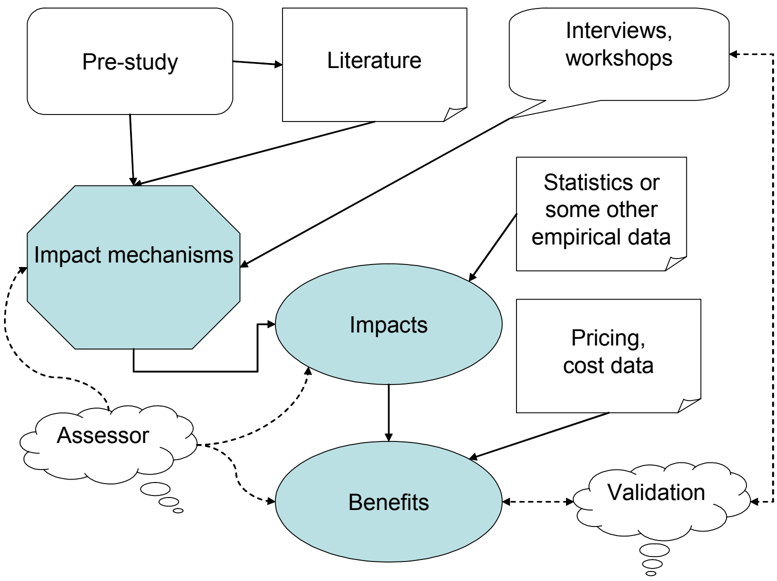


Figure 4. A meta-method description.

The sector-specific studies vary considerably as regards to depth and coverage. The reasons for this are mainly pragmatic: (1) some sectors did receive more attention and resources, (2) for some sectors the needed data varied substantially, both in terms of quantity and quality.

Finally, each researcher responsible for sector-specific analysis had the freedom of choosing the appropriate methods and approaches dictated by the limitations in scope and resources.

2.3 Benefit-cost analysis

Usually benefit-cost analysis is performed as an investment calculus, by discounting the identified benefits and costs to the present and comparing either the net present value or the ratio between the present value benefits and present value costs. When an incremental analysis, or marginal analysis meaning essentially the same thing here, is performed, the cost side comes from a marginal investment made and the benefit side comes from the marginal gains that the investment generates. A number of text books have been issued on the subject, e.g. Brent (1996) and Gramlich (1998).

In this study, a cross-sectional approach is adopted. The total benefits generated by the hydrological and meteorological information services to different stakeholders and customers are compared to the total costs allocated for the production of these services. In practice in the case of DHMZ the latter is represented by the annual budget of DHMZ.

By adopting the above described method some problems typical in benefit-cost analysis are circumvented:

- the time value of money (benefit or cost) is irrelevant as there is no need to do present value calculus
- the question of appropriate time horizon becomes irrelevant
- the *ex ante* assumptions always related to benefit or cost projections so the future can be disregarded.

However, one time horizon issue remains to be solved and this is discussed in the following chapter.

2.4 Present and potential benefits

Based on utility and decision theories academics such as Williamson (1982), Hilton (1979), Repo (1989) and Lawrence (1999) have presented methods to value information in different decision making situations. Basically, it is possible to work with two concepts:

- **the value of current information**, which may be somewhat incomplete and does not fully comply with information value attributes, but which even with its deficiencies produces value to its users; this is analogical to the situation where usable, but incomplete weather information is supplied to the users who more or less cleverly are able to utilise the information
- **the value of perfect information**, which represents the theoretical maximum benefit that the information is able to generate; the value attributes are all fully complied with by the distributed information.

It also possible to attach probabilities related to these information concepts, but it is equally possible to include probabilities to the set of value attributes (see Herrala 2007).

The value of information is directly applicable to Figure 1 context. Perfect information is correct, reliable, penetrating the market throughout, is received by all parties that need it, is understandable and therefore has the maximum impact in changing the behaviour and decisions of those parties. Currently, as we know, this is not the situation. We could even speak about "information market imperfections", to use the terminology of economics.

2.5 Benefits and their pricing

In sector-specific analyses the benefits external to DHMZ comprise of:

- savings in accident costs due to increased safety; these include both material and human values
- savings in operation costs of various operators, such as airline operators, maintenance operators of roads, airports, facilities or electricity lines
- savings in environmental costs due to lowered risk of encountering or experiencing environmental damage, such as oil spills at sea, and due to reduced exhaust levels of combustion engines
- savings in other potential weather-driven damages, such as moistened construction structures.

Each sector analysis will look at the existing and potential benefits from a slightly different angle, depending on the impact mechanisms identified and available data according to Figure 4.

The valuation of benefits is often done by utilizing the FMI (Finnish Meteorological Institute) case study performed by VTT (Hautala et al. 2007). The values used in Finland were exchanged to corresponding Croatian values by Price Level Coefficient (PLC). PLCs were derived with the help of Purchasing Power Parities (PPP). PLC is derived as follows:[4]

Gross Domestic Product per capita adjusted for purchasing power, year 2005, Finland = 32 678 USD

Gross Domestic Product per capita adjusted for purchasing power, year 2005, Croatia = 13 342 USD
PLC to adjust Finnish values to Croatian economy = 0.41.

[4] Source: Statistics Finland information services.

The simplified logic here implies that whatever cost comparison is made, the unitised consumers' purchasing power of money represents a comparable yardstick to measure costs and benefits. In reality, different sectors (e.g. transport, energy) and different inputs (labour, material, capital, etc.) have different parities and thus different ratios. Furthermore, some input commodities might have more or less the same market price in Finland and Croatia, such as fossil fuels. However, in this type of analysis these sources of error are probably not dominant. More severe bias possibilities are related e.g. to impact mechanisms. The calculated ratio lacks a currency unit, so it can be directly applied to Finnish euro values, with the aforementioned limitations and restrictions of course.

One of the most substantial benefits from hydrological and meteorological information services comes from increased safety of humans and reduced number of injuries and fatalities. The concept of *value of statistical life* (*VOSL*) is crucial. *VOSL* can be calculated as suggested by the High Level Group on Infrastructure Charging (Advisors to the High Level Group 1999), based on Swedish practice in road infrastructure projects:

$$VOSL = WTP + NLP + HLC + ADM + PDV,$$

where *WTP* = Willingness to pay; WTP consists further of two components: "pure human value" and "lost consumption"
NLP = Net lost production
HLC = Hospital care cost
ADM = Administration cost
PDV = Property and material damage cost.

The Finnish practice is identical (Tiehallinto 2006) to that above and is applied across the whole transport sector. Of these components, "pure human value" is the greatest and "lost consumption" ranks second. *VOSL* is not a uniform concept when it comes to injuries in different sectors because e.g. traffic accidents cause different type of injuries and damages than e.g. accidents on construction sites. But since in the transport sector *VOSL* is based on empirical analysis and thus represent a reliable cost estimate it has been applied throughout this study assuming that the error of cross-application is far less than the error of excluding *VOSL* entirely or adjusting it ambigously. Furthermore, the difference in fatalities is less than the differences in pure injury accidents (i.e. accidents not leading to fatalities) and yet the greatest benefit comes from saving lives.

VOSL values have been adjusted with *PLC* from Finnish values to Croatian corresponding values.[5]

[5] Authors' note: the practice of applying *VOSL* is fairly rare, even in many European and Western countries. In the Nordic countries the socio-economic investment analysis is probably most advanced.

2.6 The data

The data used for benefit calculus varies by sector. In some sector analysis (e.g. road and maritime transport) the data is fairly specific and quantitative models are employing the data. Other sectors, such as railways, are approaching the assessment of benefits in a more general manner using inductive logic[6]. Table 1 highlights the data used in the analysis of different sectors and the main benefits that the analysis is focusing on.

Table 1. The data, pricing principles and the main benefits analysed.

Sector	Data	Valuation, pricing	Benefit focus
Transport			
- Road	Literature, Finnish and Croatian statistics, expert interviews, workshops	Finnish average unit costs for accidents adjusted with *PLC*; expert estimates on road maintenance costs	Accident reduction, operative road maintenance
- Maritime	Literature, Finnish and Croatian statistics, expert interviews, workshops	Finnish average unit costs for accidents adjusted with *PLC*; expert estimates on maritime operations; cost of environmental damage repair and prevention; cost of material damages (cargo)	Accident reduction, maritime rescue operations, material damage savings
- Aviation	Finnish and Croatian statistics	Market prices, unit prices of exhausts	Fuel economy of airline operators, environmental benefits
- Railways	Finnish and Croatian statistics and railway company information, literature	Finnish average time values adjusted with *PLC*	Passenger time savings, track maintenance cost reduction
Building construction and facilities management			
	Finnish and Croatian statistics	Expert estimate	Construction contractors benefit especially during *in situ* phase; substantial benefits in the reduction of damages that appear over a lengthy period of time
Energy production and distribution			
	Croatian statistics, annual reports, direct discussions	Expert estimate, market prices	Savings in material losses and working time, improved demand prediction
Agriculture			
	Literature, Croatian and Finnish statistics	Expert estimate	Reduction of crop losses due to more efficient and enhanced protective actions

Even the environmental costs are valued in investment and decision appraisal. The idea behind this reasoning is that markets are always imperfect when it comes to valuation of human and environmental values. By having these valued, investments and decisions are evaluated from wider and more rational perspective than when including only real cash flows in terms of business economics. This is regarded a particularly important criteria in public investments and decisions.

6 If there are certain benefits to be identified in e.g. Finland and UK, there are roughly the same types of benefits in Croatia if the impact mechanisms can be assumed to be somewhat similar.

3. DHMZ – facts and figures

Observations

The current observation network fulfils the requirements of WMO. The table below (Table 2) shows the observation network[7] of DHMZ in 2007.

Table 2. DHMZ observation infrastructure.

Type of station	Number of stations[8]
Atmospheric domain	
Surface meteorological stations	41
Climatological stations	116
Precipitation stations	336
Automatic meteorological stations	34
Radiosonde stations	2
Pilot balloon station	1
Radar stations	3 + 5
Atmospheric composition (pollution) stations	20
Oceanic domain	
Ship meteorological observations	15 + 30
Coastal observation stations (depending on the parameters)	7 + 21
In-situ measurements (automated)	2 + 1
Terrestrial domain	
Hydrological observations (depending on the parameters)	100 + 500
Snow stations	483
Soil observations (depending on the parameters)	21 + 57

Additionally, there are more than 400 stations run by other organizations[9].

[7] Direct information from DHMZ in November 2007.
[8] In case of two figures, e.g. $x + y$, the first (x) indicates the number of stations that can deal with a more or less complete set of parameters; the second figure (y) indicates the number of stations where only a limited number of parameters are measured.
[9] Includes other observers' stations, such as those of the highway authority, power plants, oceanographic institutes, etc.

Information technology and data processing

The configuration of the existing IT and data processing system is presented in Figure 5. Very similar systems are being used in many meteorological services and the overall architecture works without any significant problems.

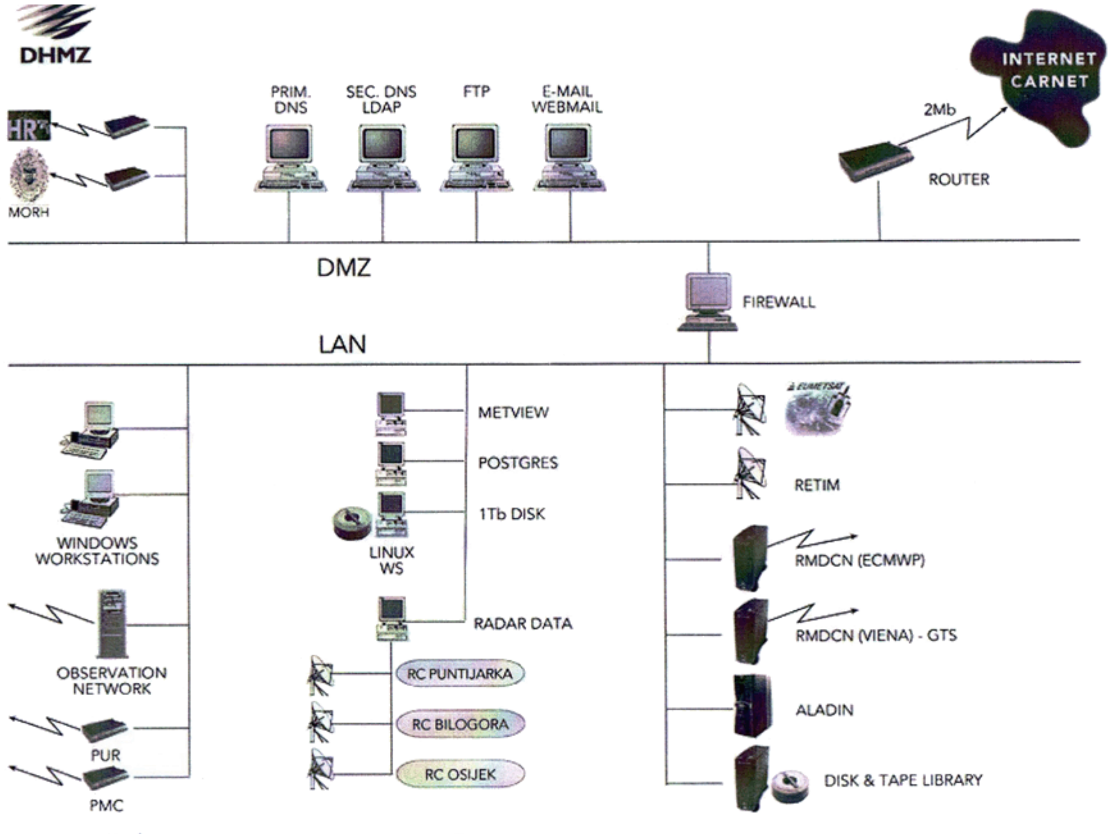
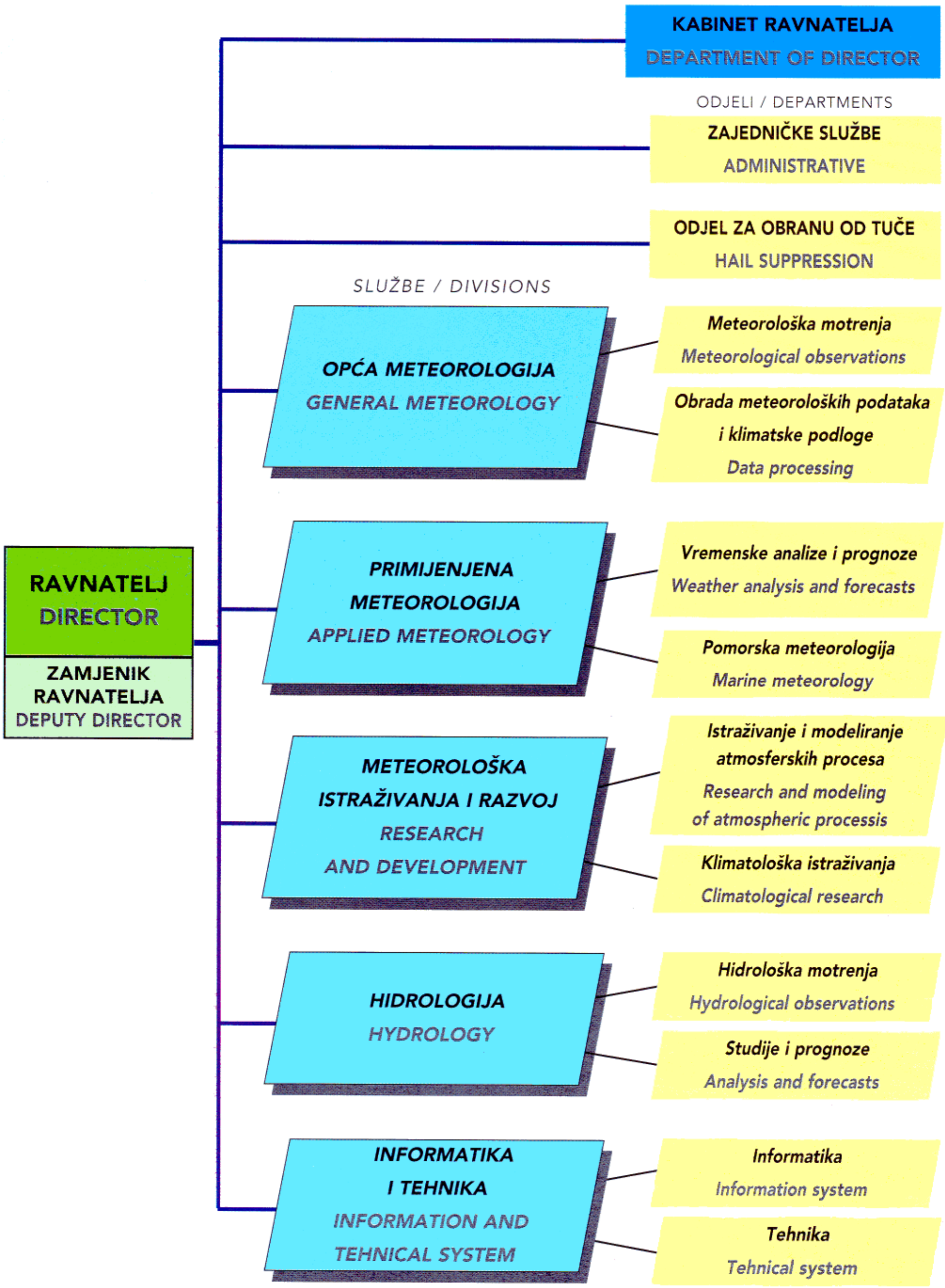


Figure 5. IT architecture of DHMZ.

Organisation

The existing organisation is outlined in Figure 6. It is divided into five divisions and three separate departments.



Ustrojstvena struktura Državnog hidrometeorološkog zavoda
The MHS organisation structure

Figure 6. Current organisation of DHMZ.

Personnel

In 2007, the total number of DHMZ staff is 421, divided between departments as follows[10]:

Department of the Director	1 + 6
Administration	26
Hail suppression	83
General meteorology	
Observations	108
Data processing	16
Applied meteorology	
Analysis and forecasts	23
Marine meteorology	26
Research and development	
Numerical models and atmospheric processes	16
Climatology	16
Hydrology	40
Information and technical system	
Information	18
Technical system	42
TOTAL	421

Qualification of staff according to educational background is as follows:

Primary or secondary school	17%
High school	54%
College degree	7%
University degree	16%
M.Sc. degree	4%
D.Sc. degree	2%
TOTAL	100%

Economy

DHMZ is a state agency which receives most of its financing through the state budget. About 15% of the income is received from commercial services, i.e. from paying customers. The investments are mainly financed through supplementary budgets.

The 2005 total budget of DHMZ was 82 million HRK (about 12 million €). This figure includes the hail suppression function. As the benefits of hail suppression are not evaluated in this report, the share of the budget comprising the standard hydro-met services and activities was about 57 million HRK (about 8 million €). The annual increase of the budget has been 6–8% in recent years. The total revenue from commercial customers is about 12 million HRK per annum.

[10] Direct information from DHMZ in November 2007.

4. Sector-specific assessments

4.1 Road transport

4.1.1 Introduction

In this sector analysis road transport includes both the transport itself (transport operators and drivers) and the maintenance of the road network as well as traffic control.

So far there are relatively few studies available related to the socio-economic effects of meteorological information services in road transport. Unfortunately most of them are short articles discussing a single specific topic or application. Methods and transferability of results vary from one article to another. Most of the articles were published years ago and were based on experience in different countries that differ from Croatia in many respects.

Usually there are several actors responsible for producing and delivering an information service to end-users. For example, raw data production, data processing and delivering the service to end-users may be done by different actors in the service chain. This raises the question how the benefits of the information service are divided between different actors and what are the benefits external to service chain actors.

4.1.2 Methods

The work was started with a literature study covering both printed and electronic material. The focus was on published material discussing the uses of meteorological information in road transport applications. When the literature study was completed and the basic information on road network and traffic safety in Croatia was available, the analysis proceeded to expert interviews. Some interviews were done face-to-face while others were done by email or at workshops that were organized during the project.

Applicable unit cost values were needed to calculate monetary values for the effects of meteorological information services. During the study it was found that no commonly agreed unit values exist for all relevant cost factors. For this reason, Finnish unit cost values calculated by the Finnish Road Administration were utilised when giving monetary values to effects on traffic safety. These Finnish values were adjusted to reflect the differences in purchasing power between Finland and Croatia. Cost information related to the winter maintenance of roads was gathered from expert interviews.

The benefits of meteorological information services were calculated on the basis of the services and distribution channels available at present. In the future, benefits may be different because of changes in meteorological information services available and the way in which meteorological information is used.

In order to determine the socio-economic effects of the operations of DHMZ, the approach used in this analysis was to first calculate the gross value of benefits and then determine how large a share of it should be attributed to DHMZ. The share of DHMZ was calculated by multiplying the market share of DHMZ by the weight coefficient of the part of the value chain and then summing over all parts of the value chain (Figure 7).

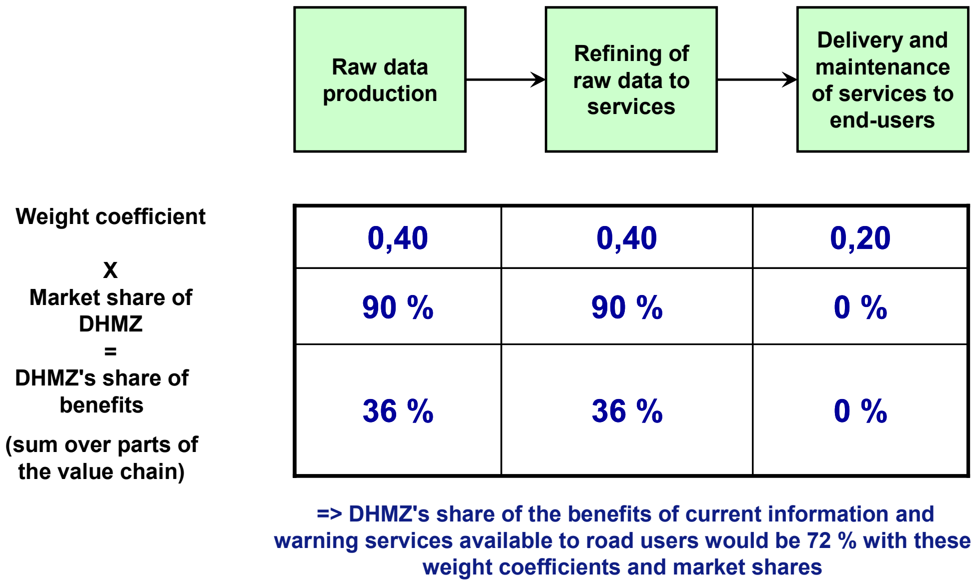


Figure 7. The method to calculate DHMZ's share of the benefits of an information service.

The value chain was divided to production of raw data, refining raw data to information services and delivery of service to end-users. The weight coefficients of different parts of the value chain are based on the consumption of resources such as hours of labour, office space, materials and equipment. The values of weight coefficients in this analysis are based on the subjective estimate of the author. The market share of DHMZ was estimated on the basis of expert interviews.

By multiplying the weight coefficients (m_i) with market shares (c_i) in different stages of the value chain, one can calculate, how large share (M) of the benefits can be attributed to an actor (formula 1)

$$M = \sum c_i \times m_i \qquad (1)$$

4.1.3 Results

Road winter maintenance

The use of road weather information systems (RWIS) have been relatively well documented in research reports and other documents. A study based on experiences in the US concluded that road weather information systems both improve driver information and contribute to cost savings related to reduced staff and equipment requirements and reduced use of salt. Meteorological information helps to bring the right equipment and materials at the right place at right time, makes it possible to implement better response strategies and helps with decisions (as an alternative to "do nothing") when appropriate. (Boselly 2001)

A Roadside RWIS system provides information on the present road and weather conditions. To produce a forecast on weather and road conditions, accurate enough mathematical models for atmosphere and road surface are needed. The correct timing of operations is critical to both traffic safety and efficiency of operations (Boselly 2001; Finnish National Road Administration 2001).

Significant reductions have been reported in the use of road salt because of meteorological information services used by organisations responsible for road winter maintenance. In the United Kingdom improved meteorological information services resulted in 20–25 % decrease in the use of road salt (Thornes 1990). Even larger reductions (30–50%) have been reported by Kempe (1990).

In Finland, improvements in meteorological services have had an effect on the use of road salt. The trend of the tons of salt used in a year has been declining since the beginning of 1990s (Finnish National Road Administration 2006). Part (5%) of this reduction can be attributed to the improvement in meteorological services available (Rusanen 2006). In Finland the unit cost for a ton of salt is about 200 €, which covers both the material (NaCl) and spreading the salt on public roads (Rusanen 2006).

An essential part of road winter maintenance in Croatia is spreading salt to make road surface less slippery. According to an expert interview, about 4 million € every year is used in spreading salt (NaCl) and calcium chloride (CaCl) on highways in Croatia. Because every maintenance centre is responsible for about 60 road kilometres and the speed of maintenance trucks spreading salt is about 30 km/h, a warning of slippery road conditions is needed at least two hours before the road surface becomes slippery. If no warning is issued, the maintenance organisation is not able to act within required time.

Operational decisions such as when to start spreading salt are made by maintenance centre managers. Currently, no localised short-term warning service is available to them. Weather forecasts are available to maintenance centre managers, but these forecasts are not localised and not produced by DHMZ. Weather stations are connected to local maintenance centres. This means that they are the only source of real-time weather data available to maintenance centre managers. The information collected by road weather stations is not used by DHMZ.

In addition, there are other organisations responsible for winter maintenance of roads such as Croatian Roads and local authorities. Organisation and operating procedures may differ from Croatian motorways, but technology and climate is the same for all such actors.

If localised short-term warning and forecasting services were available, more sophisticated response strategies could be deployed. With no localised forecasts available, maintenance centre managers can only respond to existing weather and road conditions but not act proactively. There are several situations, in which acting beforehand leads to significant benefits. For example, removing existing ice on road surface is more costly than preventing ice from forming on road surface by salting.

In Finland, the amount of the road salt used per year has declined since the beginning of 1990s. According to an expert interview, a 5% decline was attributed to more localised short-term forecasting and warning services of weather and road conditions. In Croatia 6.7 million € is spent on salting of roads per year of which 4 million € is spent on highways. If expenses are assumed to be directly related to the tons of salt used and a similar reduction in tons of salt used is assumed, savings worth 200 thousand € a year can be expected, if localised short-term warning and forecasting services were available. Only effects on salting of highways were included when calculating this estimate. If similar effects were assumed also on state and local roads, the estimate would be 335 thousand € per year.

At present, short-term forecasting services are available to organisations responsible for road winter maintenance. Unfortunately, these forecasts are not localised and no nowcasting and warning services are available. According to an expert interview, present forecasts are used to support decision-making. If no forecasts were available, more staff would be needed for monitoring the weather and road conditions. In addition, less information would be available to support the decision-making process. This means that response times to changing weather and road conditions would be longer and more resources would be needed to achieve the same level of service. The author assumes conservatively, that the increase in the consumption of resources would cause a 5% increase in costs. With previously presented figures this equals 335 thousand € for the whole road network and 200 thousand € for highways only.

At present Croatian Motorways does not use weather forecasts produced by DHMZ. Because the service provider producing the forecasts and details related to the service is not known; the market share of DHMZ in the different parts of the value chain could not be estimated.

Forecasting and warning services to road users

In several countries a large share of accidents in road traffic is related to weather and weather-related road conditions. Controlling the vehicle is a harder task to the driver, when there is ice or snow on the road surface. In addition, rain and fog have an adverse effect on visibility.

Drivers have several ways to adapting their behaviour to adverse driving conditions. Depending on the situation, an individual driver may lower his or her speed, choose a different route to destination, reserve more time for the journey, change the mode of transport or cancel the trip.

In Croatia a small percentage of road accidents involving personal injury or death happen in adverse weather conditions (Table 3). According to the figures supplied by the Ministry of Internal Affairs there were 13 fatal road accidents in adverse weather conditions with snow or fog in 2005. At the same time there were 550 such accidents involving personal injury.

Table 3. Road accidents and weather in Croatia during 2005 (Ministry of the Interior Affairs 2006).

Meteorological conditions	Road Accidents					
	Total	%	Death	%	Injury	%
Clear	35 080	60.3	325	61.3	9 411	62.1
Cloudy	13 927	24.0	129	24.3	3 450	22.8
Rain	6 525	11.2	62	11.7	1 680	11.1
Fog	585	1.0	7	1.3	170	1.1
Snow	1 835	3.2	5	0.9	376	2.5
Sleet (snow/rain)	13	0.0	1	0.2	4	0.0
Other conditions	167	0.3	1	0.2	58	0.4
TOTAL	58 132	100	530	100	15 149	100

At present, weather-related warnings are distributed to road users via radio (Croatian Radio, HRT-2), internet (www.hak.hr, www.hac.hr, www.arz.hr) and television. No statistics of the amount of warnings issued was available during the study. Warnings distributed by HRT, HAK and HAC are produced by DHMZ. The production and distribution of meteorological information and warning services targeted to road users is described in Figure 8.

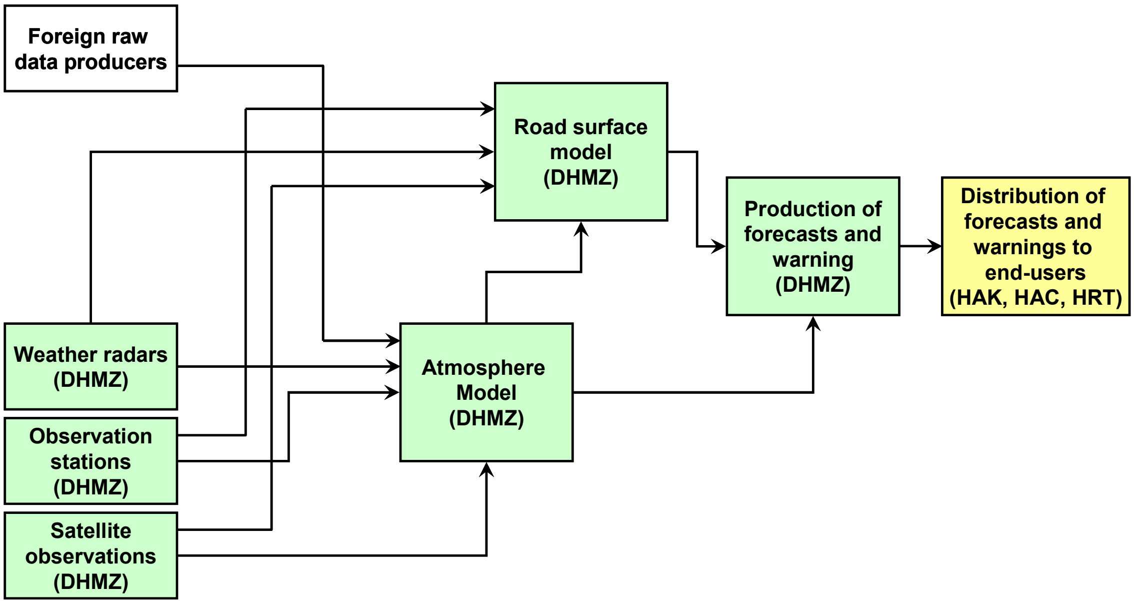


Figure 8. Production of meteorological information and warning services for road users.

At present, relatively few studies are available on the effects of meteorological information and warning services on traffic safety. According to an expert interview, information and warning services targeted to road users reduce the number of road accidents involving personal injury or death by 1–2% (Kulmala 2006) on public roads. This result applies to Finland, where weather and road conditions are more challenging than in Croatia. In Finland, 21.4% of deaths and 22.3% of injuries in road accidents happen, when road surface is snowy, slushy or icy (Statistics Finland 2006). In Croatia, the 2.54% of road accidents involving death and 3.63% of accidents involving personal injury happen, when there is fog or snow or ice on the road surface. The Finnish figure (1–2% reduction) has to be scaled to be applicable to Croatian conditions. The reduction in fatal road accidents in Croatia would then be

$$r_{cro} = r_{fi} \times \frac{a_{cro}}{a_{fi}} \qquad (2)$$

in which a_{cro} is the share of fatal road accidents happening in adverse weather conditions in Croatia and a_{fi} is the share of fatal road accidents happening in adverse weather conditions in Finland. r_{fi} in formula is the reduction of fatal road accidents on public roads in Finland because of information services to road users. All the previous figures (r_{fi}, a_{cro} and a_{fi}) are percents. The reduction in fatal and injury accidents was assumed to be same.

The reduction in the number of fatal road accidents on public roads in a year was calculated with equation

$$x = \frac{1}{1 - r_{fi} \times \frac{a_{cro}}{a_{fi}}} \times c_{fatal} - c_{fatal} \tag{3}$$

in which c_{fatal} is the number of fatal road accidents on public roads in Croatia and x is the number of fatal road accidents avoided because of present information services. For c_{fatal} year 2005 figure (530) was used. Reduction in injury accidents on public roads was calculated with the same kind of equation

$$y = \frac{1}{1 - r_{fi} \times \frac{b_{cro}}{b_{fi}}} \times c_{injury} - c_{injury} \tag{4}$$

in which c_{injury} is the number of injury accidents in a year on public road in Croatia. Year 2005 figure (15 149) was used for c_{injury}.

Meteorological information and warning services also reduce the number of accidents causing only property damage. According to an expert interview (Kulmala 2006), the effect of meteorological information and warning services targeted to road users is based on both lower speeds and increased vigilance of road users. According to Nilsson (2004), the relation between the number of accidents involving personal injury or death and average speed of vehicles is described by formula

$$\frac{c_{fatal}(after) + c_{injury}(after)}{c_{fatal}(before) + c_{injury}(before)} = \left(\frac{V_1}{V_0}\right)^2 \tag{5}$$

in which V_0 is the average speed of vehicles before the change in speed and V_1 is the average speed after the change in speed (Nilsson 2004). Nilsson has also presented a formula, which describes the relation between average speed and number of fatal road accidents

$$\frac{c_{fatal}(after)}{c_{fatal}(before)} = \left(\frac{V_1}{V_0}\right)^4 \quad \text{(Nilsson 2004)} \tag{6}$$

Models formulated by Nilsson have their relations to the kinetic energy of a vehicle and the braking distance, which increase in proportion to the square of the speed of the vehicle. According to an expert interview, the relation between average speed of vehicles and the number of accidents involving only material damage can be described with formula

$$\frac{c_{property}(after)}{c_{property}(before)} = \frac{V_1}{V_0} \qquad \text{(Kulmala 2006)} \quad (7)$$

In addition to change in speed, the increased vigilance of road users reduces the number of accidents. The accident reduction because of the increased vigilance was assumed to be related to the average speed of vehicles with formula

$$\frac{c_{property}(after)}{c_{property}(before)} = \left(\frac{V_1}{V_0}\right)^2 \qquad \text{(Kulmala 2006)} \quad (8)$$

According to an expert interview, the effect of meteorological information and warning services on accidents involving only property damage is related to both lower speed and increased vigilance of road users. The reduction in accidents causing property damage only can be estimated with the two previous formulas. The effect on the number of accidents involving only property damage is then described by equation

$$\frac{c_{property}(after)}{c_{property}(before)} = \frac{1}{2}\left(\frac{V_{after}}{V_{before}}\right) + \frac{1}{2}\left(\frac{V_{after}}{V_{before}}\right)^2 \qquad (9)$$

in which $c_{property}(before)$ is the number of accidents causing only property damage in situation in which the present information services aren't available and $c_{property}(after)$ is the number of corresponding accidents at present (Kulmala 2006). When

$$\left(\frac{V_{after}}{V_{before}}\right)^2 \qquad (10)$$

is replaced by the left side of equation 5 in equation 9, the accidents involving only property damage are expressed in terms of accidents involving personal injury or death

$$\frac{c_{property}(after)}{c_{property}(before)} = \frac{1}{2}\sqrt{\frac{c_{fatal}(after) + c_{injury}(after)}{c_{fatal}(before) + c_{injury}(before)}} + \frac{1}{2}\frac{c_{fatal}(after) + c_{injury}(after)}{c_{fatal}(before) + c_{injury}(before)} \qquad (11)$$

Because $c_{fatal}(after)$ and $c_{injury}(after)$represent the present amounts of injury and fatal accidents in a year, $c_{fatal}(before)$ and $c_{injury}(before)$ have to be calculated "backwards".

In this formula they represent a situation in which the present information and warning services to road users aren't available. They can be calculated with formulas

$$c_{fatal}(before) = c_{fatal} + x \quad (12)$$

$$c_{injury}(before) = c_{injury} + y \quad (13)$$

and naturally

$$c_{fatal}(after) = c_{fatal} \quad (14)$$

$$c_{injury}(after) = c_{injury}. \quad (15)$$

Reduction p in property damage only accidents can be calculated with equation

$$c_{property}(after) = c_{property}(before) \times (1-p)$$
$$(1-p) = \frac{c_{property}(after)}{c_{property}(before)} \quad (16)\ (17)$$

which gives the reduction in percents. By substituting the right part of the equation with the right side of equation 11, we get

$$(1-p) = \frac{1}{2}\sqrt{\frac{c_{fatal}(after) + c_{injury}(after)}{c_{fatal}(before) + c_{injury}(before)}} + \frac{1}{2}\frac{c_{fatal}(after) + c_{injury}(after)}{c_{fatal}(before) + c_{injury}(before)} \quad (18)$$

By multiplying both sides with –1 and moving –1 to another side of equation we get a formula for p, the reduction of property damage only accidents in percents

$$p = 1 - \frac{1}{2}\sqrt{\frac{c_{fatal}(after) + c_{injury}(after)}{c_{fatal}(before) + c_{injury}(before)}} - \frac{1}{2}\frac{c_{fatal}(after) + c_{injury}(after)}{c_{fatal}(before) + c_{injury}(before)} \quad (19)$$

The number of avoided accidents involving only property damage was then calculated with formula

$$z = \frac{1}{1-p} \times c_{property} - c_{property}$$
$$z = \frac{1}{1 - \left(1 - \frac{1}{2}\sqrt{\frac{c_{fatal}(after) + c_{injury}(after)}{c_{fatal}(before) + c_{injury}(before)}} - \frac{1}{2}\frac{c_{fatal}(after) + c_{injury}(after)}{c_{fatal}(before) + c_{injury}(before)}\right)} \times c_{property} - c_{property}$$

(20)

In future, more localised and personalised information services will have an even larger effect on the safety of road users. They have been estimated to reduce the number of accidents involving death or personal injury by 2–4% (Kulmala 2006). Their effect on the numbers of different types of accidents were calculated by assuming the 1–2% effect on present information services, scaling the effect in percents like in formula 2, calculating "backwards" the number of accidents without present information services and then multiplying this figure with the 2 or 4% effect on the number of accidents. The reductions in accidents involving death or personal injury were calculated with formulas

$$x_f = \frac{1}{1-(r_{fi} \times \frac{a_{cro}}{a_{fi}})} \times c_{fatal} \times r_{fi(2-4\%)} \tag{21}$$

$$y_f = \frac{1}{1-\left(r_{fi} \times \frac{b_{cro}}{b_{fi}}\right)} \times c_{injury} \times r_{fi(2-4\%)} \tag{22}$$

The reduction in the number of accidents involving only property damage because of more sophisticated information and warning services to be introduced in the future was calculated with formulas

$$z_f = \frac{1}{1-p} \times c_{property} \times q$$

$$z_f = \frac{1}{1-p} \times c_{property} \times \left(1 - \frac{1}{2}\sqrt{\frac{c_{fatal} + c_{injury} - x_f - y_f}{c_{fatal}(before) + c_{injury}(before)}} - \frac{1}{2}\left(\frac{c_{fatal} + c_{injury} - x_f - y_f}{c_{fatal}(before) + c_{injury}(before)}\right)\right)$$

(23)

like in case of present information and warning services (see equation 21).

To calculate the socio-economic benefit, the numbers of avoided accidents were multiplied with relevant unit cost values. Finnish unit cost values for a fatal road accident (u_f), for a road accident involving personal injury (u_i) and for an accident involving only property damage (u_p) were used. The Finnish values were scaled down by a factor k which represents differences in purchasing power between Croatia and Finland. The socio-economic benefit in a year could then be calculated with equation

$$B = x \times ku_f + y \times ku_i + z \times ku_p$$

$$= \left(\frac{1}{1 - r_{fi} \times \frac{a_{cro}}{a_{fi}}} \times c_{fatal} - c_{fatal} \right) \times ku_f + \left(\frac{1}{1 - r_{fi} \times \frac{b_{cro}}{b_{fi}}} \times c_{injury} - c_{injury} \right) \times ku_i + z \times ku_p \qquad (24)$$

The value of *k* was 0.43 (0.43188 to be exact). This multiplier was calculated by dividing the GDP (50 831 million €) per capita (4,439 million inhabitants) of Croatia with corresponding figure of Finland (139 332 million €, 5.255 million inhabitants). The value of GDP used in the calculation was adjusted with the purchasing power parity. Statistics used to calculate multiplier *k* were taken from WIIW Handbook of Statistics (Vienna Institute for International Economic Studies 2006)[11].

The share of DHMZ of the socio-economic benefit was calculated with formula

$$M = \sum c_i * m_i$$

in which c_i is the weight coefficient of the part of the value chain and m_i is the market share of DHMZ in the part of the value chain. The value chain was divided to three parts: production of raw data (1), data processing and refining it to services (2), offering and delivering service to end-users (3). For present information services targeted to road users (nowcasts, forecasts and warnings in the mass media) the coefficients were assumed to be c_1 = 40%, c_2 = 40% and c_3 = 20%. The production process has been outlined in figure 8. The market shares of DHMZ in the different parts of the value chain have been assumed to be m_1 = 90%, m_2 = 90% and m_3 = 0%. The DHMZ's share of the socio-economic benefits of the present meterorological information services targeted to road users is then

$$M_{present} = \sum_{i=1}^{3} m_i \times c_i = m_1 \times c_i + m_2 \times c_2 + m_3 \times c_3 = 0{,}9 \times 0{,}4 + 0{,}9 \times 0{,}4 + 0 \times 0{,}2 = 0{,}72$$

DHMZ's share of the benefits of more localised and personalised information services to be introduced in the future was calculated in a similar way. Because of differences in technical solutions, organisation and business models, different values for the weight coefficients were used (c_1 = 35%, c_2 = 35% and c_3 = 30%). Because these services do not exist at present, the market shares of DHMZ were estimated by the author. The author also assumes that in future most raw data is collected by DHMZ, as DHMZ has a significant role in data processing and production of services and DHMZ may also offer some services directly to end-users. Values of the market shares of DHMZ in future information services are based on previous assumptions (m_1 = 90%, m = 50% and m_3 = 30%).

[11] Editor's note: slightly different coefficient is used here due to different authors' varying references. However, the difference between coefficients (0.43 and 0.41) was regarded insignificant given the other probable error sources.

Table 4. Benefits of the weather information targeted to road users (present information services).

	low	high
Accidents involving personal injury on public roads (2005)	15 149	15 149
Fatal road accidents on public roads (2005)	530	530
Accidents involving property damage only on public roads (2005)	42 453	42 453
The effect of information on the number of accidents causing property damage only	0.13%	0.25%
The effect of information on the number of injury accidents	0.17%	0.34%
The effect of information on the number of fatal accidents	0.11%	0.23%
Injury accidents without present information services	15 147.81	15 200.71
Fatal road accidents without present information services	530.60	531.21
Accidents involving property damage only without present information services	42 506.63	42 560.41
Injury accidents avoided with present information services	25.81	51.71
Fatal road accidents avoided with present information services	0.6	1.21
Accidents involving property damage only avoided with present information services	53.63	107.41
Socio-economic benefit of the information service / million €	4.32	8.65
The DHMZ's share of benefits	72.00%	72.00%
Benefits attributed to DHMZ / million €	**3.11**	**6.23**

Table 5. Benefits of the weather information targeted to road users (more localised and personalised information services).

	low	high
Accidents involving personal injury on public roads (2005)	15 149	15 149
Fatal road accidents on public roads (2005)	530	530
Accidents involving property damage only on public roads (2005)	42 453	42 453
The effect of information on the number of accidents causing property damage only	0.25%	0.51%
The effect of more localised and personalised information services on fatal accidents	0.34%	0.46%
The effect of more localised and personalised information services on injury accidents	0.23%	0.68%
Injury accidents without present information services	15 147.81	15 200.71
Fatal road accidents without present information services	530.60	531.21
Accidents involving property damage only without present information services	42 506.63	42 560.41
Injury accidents avoided with future information services	51.62	103.42
Fatal road accidents avoided with future information services	1.21	2.42
Accidents involving property damage only avoided with future information services	107.45	215.60
Socio-economic benefit of the information service / million €	8.6	17.3
The DHMZ's share of benefits	58%	58%
Benefits attributed to DHMZ / million €	**5.01**	**10.03**

$$M_{future} = \sum_{i=1}^{3} m_i \times c_i = m_1 \times c_i + m_2 \times c_2 + m_3 \times c_3 = 0{,}9 \times 0{,}35 + 0{,}50 \times 0{,}35 + 0{,}30 \times 0{,}30 = 0{,}58$$

Results of calculations with previous formulas are shown on Tables 4 and 5.

4.1.4 Conclusions

The effects of the meteorological information services on road traffic sector in Croatia are mainly related to meteorological information services targeted to road users and to the use of meteorological information in road winter maintenance operations. The results are based on models derived from literature studies, several expert interviews and the results of similar studies carried out in Finland.

The most significant effects of meteorological information seem to be related to information and warning services offered to road users. According to the results of the study, present information and warning services on weather and road conditions reduce the number of different types of road accidents. The effect of present information and warning services was estimated to be 0.6–1.2 fatal accidents, 26–57 accidents involving human injury and 54–107 accidents involving property damage only per year. The socio-economic benefit related to the reduced number of accidents was estimated to be 4.3–8.7 million € per year.

In future, more sophisticated information and warning services will be available to road users. These services will be more localised, personalised and context-aware than present information services which are mostly based on mass communication via radio and television. The effect of more sophisticated information and warning services was estimated to be 1.2–2.4 fatal accidents, 52–103 accidents involving human injury and 107–212 accidents per year involving property damage only. The socio-economic benefit related to the reduced number of accidents was estimated to be 8.6–17 million € in a year compared to situation in which there are no weather-related information and warning services available to road users.

It is probable that meteorological information can reduce the costs of road winter maintenance. If the winter maintenance operator is able to act before the snow falls or ice forms on the road surface, the same quality of maintenance can be achieved with a smaller amount of resources such as materials, working hours or fuel. At present, winter maintenance managers have access to weather forecasts, but these forecasts are not localised and they are not tailored to support winter maintenance operations. In future, winter maintenance operators will have access to localised forecasts tailored to support their work and extensive real-time data on weather and the status of road surface. If a 5% reduction in the use of materials and costs is assumed, the benefit for improved weather and road surface information would be at least 0.34 million € per year. The previous estimate is rather conservative, because it includes only effects on the use of road salt. Impacts on other operations included in winter maintenance such as snow removal or use of abrasives are not counted for.

4.2 Rail transport

4.2.1 Introduction and background

Last year, in 2006, Croatian Railways (HZ, Hrvatske Željeznice) carried more than 46 million passengers and more than 15 million tonnes of cargo (UIC 2007[12]). The rail transport has been increasing and the projected rail transport flows are estimated to grow by more than 30% for 2001–2015 and more than 60% for 2001–2025 (European Commission 2003) (see Table 6).

Table 6. Rail transport volumes in Croatia.

		2005	2006	Projected growth 2001–2015	Projected growth 2001–2025
Passenger flows	million passengers	39.8	46.2	33%	62%
	million passengerkm	1.27	1.40		
Freight flows	million tonnes	14.3	15.4	39%	74%
	million tonnekm	2.84	3.31		

HZ has been under restructuring and the current structure resembles to that of most European rail corporations (see Krakić 2007 for the structure of Croatian railways).

4.2.2 The method of evaluation

Since there was no statistics available concerning the reliability or safety[13] of HZ, the estimate of potential benefits is carried out by scaling the results of Finnish case study (Hautala et al. 2007). Based on earlier work of Smith (1990), Thornes & Davis (2002) and Levo et al. (2004) Hautala et al. (2007) estimated that about 20% of all the delays were somehow weather-related and that about half of them could be in the best case

[12] http://www.uic.asso.fr/stats/

[13] Number of accidents and especially weather-resulted accidents as a safety indicator; timetable reliability and especially weather-resulted delays of departures and arrivals.

eliminated by utilising more sophisticated weather information more efficiently. Naturally, these assumptions, even though partly based on empirical analysis, have to be taken as "best guesses". The Croatian weather circumstances are not that severe as in Finland, but on the other hand the Finnish Railways (VR) performance on reliability is the top class in Europe.

The Finnish benefit values are adjusted with purchasing power parity with factor 0.41.

If the statistics would have been available, alternative valuation methods on the benefits could have been made, based on e.g. the work of REBIStransport Joint Venture Analysis (European Commission 2007) which delivered some time and accident values for transport.

4.2.3 Results

The potential benefits for Finnish rail transport yielding from enhanced weather information services were estimated to be around 0.5 million € per year. The main benefits come from time savings for passengers and freight and operational savings for track maintenance contractors. VR transport key figures for 2006 were

- 65 million passengers and 3.6 million passenger kilometres
- 44 million tonnes and 11 million tonne kilometres.

Hence the ratio between Finnish and Croatian transport volumes is about 46/65 = 0.71 measured by the number of passengers which reflects perhaps best how the benefits would be directed in the Croatian case.

For Croatia this would mean an annual benefit for the railway sector because of good weather information services, of magnitude of

$$0.5 \text{ million } € /a \times 0.41 \times 0.71 \approx 0.15 \text{ million } € \text{ per year}$$

The author is inclined to state that this is probably a clear underestimate, but rather something to start the discussion with. The likely beneficiaries that receive a lion's share of the benefits would be HZ-Transport (passenger time savings) and HZ-Infrastructure due to more efficient maintenance. As Croatia has some important coastal hubs of the Balkans, the benefits for both domestic (HZ-Cargo) and international freight are something to be counted for too.

4.2.4 Recommendations

According to a short informal survey, the HZ is not likely willing to pay for weather information services, but DHMZ should stay in contact with HZ, especially its infrastructure subsidiary, because when operations are streamlined ever further, the need to take exogenous factors in track maintenance more effectively into account will surely increase.

4.3 Maritime transport

4.3.1 Introduction

Historically the maritime transport needs for meteorological services have had a significant impact on the development of these services. The early development of meteorological services in many countries such as the UK, France, Germany and the United States originate from the early needs of shipping (Craft 2001) – damages to ships and their cargo incurred by storms caused great financial losses.

The goal of this analysis was to evaluate the socio-economic impacts of meteorological information services provided by DHMZ to the maritime industry. Inland waterways were considered to be a part of the evaluation. In addition to the evaluation of present services the analysis aimed at identifying the potential for increased socio-economic impact by identifying the different needs of the society and stakeholders leading to a need to further develop meteorological services. Based on the literature review made at the beginning of the analysis work, it seems that if socio-economic benefits of meteorological services to maritime transport and industry have been studied, very little or no information at all on these studies have been published. The reason for this may be that the utilisation of meteorological information is traditionally self-evident in seafaring.

Use of meteorological services in maritime traffic

Meteorological information affects a significant part of decision making onboard, but the demands for meteorological information vary among the different users and actors. For some activities in maritime transport the impact of the meteorological information is difficult to evaluate. It can be observed to be positive or negative, and in fact invariably positive, but to point out quantitative benefits more comprehensive analysis and well-justified expert estimates would be needed.

The impact areas of maritime transport are divided under four domains: safety of human beings, environment, economy and material. In this analysis the impact to maritime transport was considered from the point of view of different activities and the domains were considered to be part of these activities.

Maritime industry in Croatia

There are 14 shipping companies in Croatia and they are all members of the Croatian Shipowners' Association Mare Nostrum. 187 ships of these companies are operating internationally, altogether 1 589 955 gross registered tonnes (GRT). This figure is increasing as there are 22 new ships being built and 15 planned in the Croatian shipyards (Vidučić, V. 2004).

If the volume of goods in marine trade in Croatian ports between 1999 and 2004 is compared, it generally shows an increase of 50% during this five year period (Figures 9 and 10, Table 7).

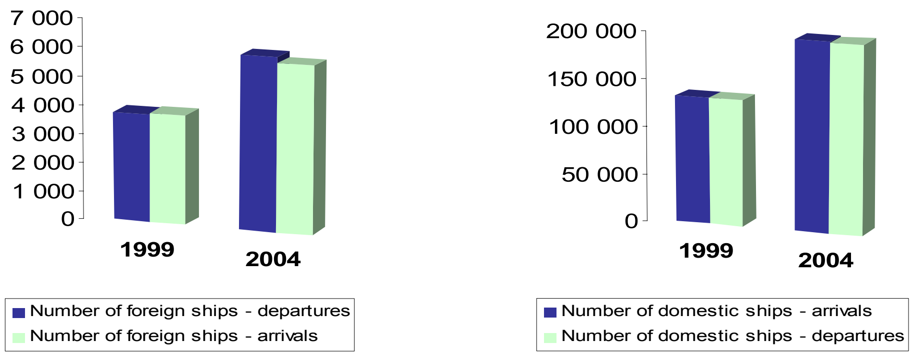
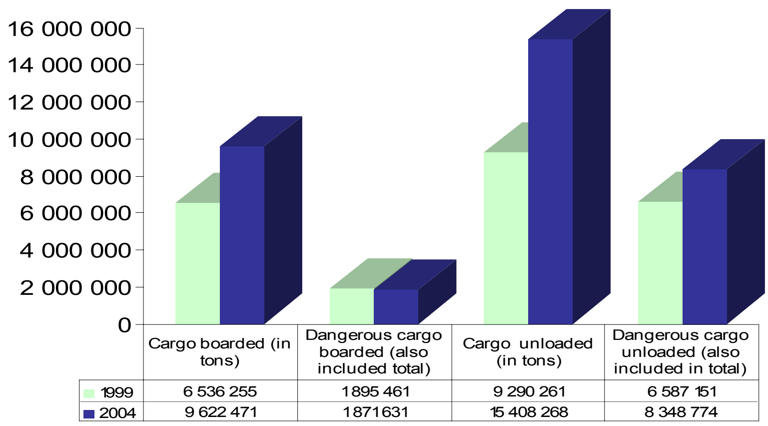


Figure 9. Marine trade in Croatian ports in 1999 and 2004 (Bačić 2005).



	Cargo boarded (in tons)	Dangerous cargo boarded (also included total)	Cargo unloaded (in tons)	Dangerous cargo unloaded (also included in total)
1999	6 536 255	1 895 461	9 290 261	6 587 151
2004	9 622 471	1 871 631	15 408 268	8 348 774

Figure 10. Amount of cargo handled in Croatian ports in 1999 an in 2004 (Bačić 2005).

Main ports of Croatia are Dubrovnik, Dugi Rat, Hvar, Korcula, Koromacno, Maslenica, Metkovic, Omisalj, Ploce, Plomin, Pula, Rab, Rasa, Rijeka, Rovinj, Senj, Sibenik, Split, Umag, Vela, Luka and Zadar. The largest port is the port of Rijeka and for passenger traffic the port of Dubrovnik which handles both cargo and cruise ships.

Tourism is an important part of the Croatian economy. In passenger vessel traffic nearly 10 million passengers' boarded vessels in Croatia in 2004 and over 10 million passengers arrived to Croatia with a ship. The amount of passengers has increased 67 per cent during the last five years. In addition more than 2.2 million cars were loaded and unloaded in Croatia from the passenger vessels during 2004 (Table 7).

Table 7. Marine trade in Croatian ports in 1999 and in 2004(Bačić 2005).

Marine trade in Croatian ports	1999	2004
Number of domestic ships – arrivals	132 364	198 556
Number of foreign ships – arrivals	3 875	5 806
Number of domestic ships – departures	132 237	198 187
Number of foreign ships – departures	3 756	6 012
Cargo boarded (in tons)	6 536 255	9 622 471
Dangerous cargo boarded (also included in 5)	1 895 461	1 871 631
Cargo unloaded (in tons)	9 290 261	15 408 268
Dangerous cargo unloaded (also included in 7)	6 587 151	8 348 774
Passengers boarded	6 101 145	9 998 916
Passengers unloaded	5 991 196	10 075 161
Cars boarded	1 519 079	2 214 838
Cars unloaded	1 546 280	2 225 769

In addition to the commercial vessels, there are also 3 700 fishing boats in Croatia and in January 2005 there were also 102 916 registered leisure boats. During the summer of the same year the number of passages made with these boats exceeded 200 000 (VTT 2006a).

Inland waterway transport offers great possibilities in Croatia. Inland waterway transport is energy efficient, quiet and relieves the congested road traffic. In terms of energy efficiency and the weight of goods, which can be moved by one kilometre with one litre of gasoline, the figure for road haulage is 50 tonnes, for rail haulage 90 tonnes and for inland waterways 127 tonnes (Beškovnik 2005). This naturally contributes also to the amount of air pollution caused and promotes the use of waterway transport as an efficient and environmentally friendly transport mode.

4.3.2 DHMZ services for maritime traffic

Basic meteorological services

DHMZ centre for meteorological services for maritime field is located in Split. It provides meteorological services for the Croatian sea areas. In addition to the general and maritime forecasts (shipping forecasts), a warning service is provided. The key clients of these meteorological services are the vessels navigating in this area, the Croatian based shipping industry and other maritime related actors. Services are not provided for the whole Mediterranean. More precisely, the services are provided for:

- shipping companies and their vessels and the shipping industry in general
- search and Rescue (SAR) organisations
- pollution mitigation at sea (oil combating etc.)
- fishing and fisheries
- boating and other recreational use of sea.

Marine meteorological department of DHMZ (OPM–SPLIT) covers all the abovementioned activities and in addition produces forecasts for road maintenance, building construction, and to general public. Forecasts to the public are given on local radio and TV broadcast at least three times a day. Forecasts are disseminated by non-stop radio messages that are updated three times a day. Forecasts are also provided at the DHMZ web-pages that are also updated at the same interval. NAVTEX radio messages are broadcasted in English with a more frequent interval, six times a day.

Figure 11. Croatia, its coastline and surrounding area of Adriatic Sea (source: http://www.map-of-croatia.co.uk).

Marine forecasts are issued in four languages, in Croatian, English, German and Italian. At present DHMZ employs two translators and additionally the services of one translator is used as an outsourcing service. Standard meteorological products (warnings, brief weather analysis, etc.) are issued for the next 24 hours. Basic data for these products are collected from selected coastal observing sites for open waters of the Adriatic Sea, coastal areas as well as for ports and anchoring areas (Figure 11).

Shipping companies, national rescue organization and the pollution mitigation authorities at sea usually monitor the standard meteorological reports for the whole Adriatic Sea in textual and graphical format, special forecast for the area of interest and, if necessary, communicate personally with the forecaster.

There are no special services for fishing and thus they mainly use information available on the Internet (DHMZ web-pages), public broadcasts (radio, TV) and newspapers. The same sources of meteorological information are also used for boating. In addition there are some separate contracts with one or a group of marinas where more local forecasts are provided.

There are different levels of responsibility in the providing of meteorological information to shipping. The European centre responsible for the provision of the general meteorological information to shipping is in France. They produce standard forecasts as short messages that can easily be received by ships. The provisioning of such general information is not a goal for DHMZ. The maritime meteorological information centre in France does not provide accurate information for narrower areas. The Adriatic Sea area could in the future be the core know-how of the DHMZ providing local forecasts accurate in content, timescale and area.

Special meteorological services

Providing of special meteorological services is based on contracts and according to the present contracts the following information is provided to the listed stakeholders:

- marine meteorological bulletins and warnings for ports and anchoring sites
- weather reports and consultations for visiting ships
- visiting Voluntary Observation Ships (VOS) and controlling instruments and observations
- marine meteorological bulletins and warnings for
  - shipyards,
  - transport of dangerous and other special cargo and
  - marine maintenance and exploration.

Services for weather routing or other route optimisation are not regularly provided, except for the purpose of the transportation of dangerous and other special cargo or oil platforms. Services are also provided when an immediate route change (passenger ships or special cargo transportation) due to locally extreme weather e.g. severe *bora wind* is required. In these cases DHMZ is normally contacted by phone.

In addition to the standard marine weather forecasts which are widely disseminated, there are some specific forecasts issued by the small unit in Rijeka which is part of the Split marine department. Services are provided for the Rijeka Port which is the largest port in Croatia. The following information is produced to Rijeka Port:

- wind forecasts especially for the south-eastern wind *jugo* that is a *scirocco* type wind and data on the waves along the docks during docking or unloading
- rain forecast for cargo handling of rain sensitive cargoes
- information on locally extreme weather for immediate route change.

Meteorological information is also provided on request for some shipyard activities e.g. painting work and launching of ships.

4.3.3 Methods

This study included a literature review, expert interviews and development of methodology for evaluation. The maritime industry sectors and related activities that were chosen to be evaluated were identified from literature and their selection verified with the views of Finnish experts. In Croatia the evaluation is based on the method of evaluation developed during the evaluation of meteorological services provided in Finland, on articles of Croatian maritime industry, information gathered from DHMZ representatives in two project workshops and information received from various information sources in Croatia from answers to two different questionnaires made during the project. These questionnaires were unstructured and based on *ad hoc* needs.

4.3.4 Results

Seven different maritime industry activities were selected to be considered when assessing the socio-economic impact of DHMZ services. These activities were (1) search and rescue (2) vessel traffic (sea traffic), (3) oil combating and pollution prevention, (4) river traffic, (5) boating and other recreational use of water areas, (6) tourism and (7) fishing and fisheries. In the following chapters the impact of present meteorological information services is discussed and the identified potential development for future services and impacts gained are described.

Safety of human beings (search and rescue)

The average annual number of maritime accidents, including river traffic is on average 1 060 accidents in Croatia (VTT 2006a). Statistics on maritime accidents that have been, to a significant extent, caused by heavy weather can be used for estimating the benefits gained by the services. Approximately three to seven people die in weather related boating accidents in Croatia annually (Tarchi et al. 2006). Estimates on how many boating accidents are annually avoided and how many lives saved were unfortunately not available. When this was evaluated in Finland, it was estimated, that 10–20 lives are saved annually with the forecasts provided to boating. If this positive impact in Croatia is evaluated to be half of the impacts in Finland, at least 5–10 lives can be saved annually.

In addition to the lives saved in accidents, the personal safety of people in the different activities of shipping industry benefits from the meteorological information services. Passengers and crews onboard vessels can take preventive measures if needed, severe fatigue among navigators and engine personnel may be avoided, and search and rescue (SAR) can plan their work more safely and effectively. The quantity of the economic benefits gained with meteorological services in personal safety in Croatia could not, however, be evaluated in this project.

In Croatia the organisation and infrastructure of maritime search and rescue (SAR) is under construction. With the development of SAR the meteorological services it requires also need to be developed. Services provided today are not accurate enough for SAR. Definition of the national search and rescue organisation and cooperative development of tailored services is now needed to increase the safety of lives in waterborne activities. Safety at sea is a national issue but also an important matter for tourists and it affects the decision making of tourists when evaluating pros and cons of different holiday resorts.

Vessel traffic

As described earlier, the amount of vessel traffic in Croatia is significant: The total number of port calls (arrivals in ports) in 2004 was 204 362 (Bačić 2005). Majority of port calls in Croatia i.e. approximately 190 000 are of domestic vessels that sail between the islands and the main land. This traffic flow is heavy and consists largely of small passenger vessels including high speed crafts (HSCs). Rijeka is the nation’s busiest cargo port and Dubrovnik is a significant passenger vessel port. The majority of oil transportation in Croatia is handled in a terminal located southeast of Rijeka. 10.2 million tons of dangerous cargo was transport to and from Croatian ports in 2004.

At present DHMZ provides several services to the maritime industry but the services are still considered insufficient. As from the point of view of boating and recreational use of sea, the forecasts are not accurate enough as the forecast areas are too large. To gain the potential benefits of meteorological services to vessel traffic requires more effort. One proposed means for this could be the establishment of Maritime meteorological services Centre of Excellence in Split. It would provide tailored services for needs of different actors in maritime industry. The improved services would not only enhance safety and the protection of environment, but also the economics of shipping companies.

Oil combating and pollution prevention

Operational pollution from ships has become a major problem within the Mediterranean region. While accidental pollution rarely occurs within the Mediterranean waters, operational pollution is a common practise in the basin, representing the main source of marine pollution from ships (Tarchi et al. 2006). According to the recently published European Joint Research Center (EJRC) study the majority of oil spills from ships are located away from the coasts (Tarchi et al. 2006; see Figures 12 and 13). A positive signal is that according to this study the number of occurred oil spills (accidental / operational pollution from ships at sea, on-shore industry near coastline, etc.) in the territorial sea and Environmental and Fisheries Zone (ZPEP) of Croatia seems to have decreased from 1999 to 2004. However, at the same time, Croatia has not implemented any specific measures to monitor the pollution of the sea.

The number and size of oil spills in the sea area where DHMZ services are utilised was not accurately defined in this project. According to Croatian experts (VTT 2006b) there has been 12–24 oil spills in Croatia annually. These spills are presumed to be mainly pollution from the on-shore industry and not actual oil spillages from ships. Some of the oil spills are leaks from the ships that have sunk a long time ago, but their fuel oil is still in the tanks. Such leaks are a common problem in many parts of the world.

Whatever may be the cause of the spill, shipping or wrecks, the need for oil pollution prevention and combating is urgent. The organisation and infrastructure of pollution prevention, mitigation and monitoring is under construction in Croatia. The future challenge for DHMZ is to develop services to support this important activity. Tailored services such as information on prevailing conditions and forecasts of wind and current for the planning and conducting of effective oil combating operations. The use and development of oil flow models may also be considered.

According to the Finnish oil combating specialists the success of oil recovery from sea is highly dependable on the weather forecasts (Hautala et al. 2007). If the forecast on the wind and the state of the sea is not available or is not accurate, the oil combating mission may fail and a significant part of the oil spill could be washed ashore. The cost of collecting spilled oil from the shores in Finland is estimated to be more than 100 € per litre. No estimates on these costs were available from Croatia. The costs can be estimated roughly using the Price Level Coefficient (PLC) leading to an estimate of cleaning costs, 41 € per litre when collecting the oil from the shoreline. In Finland a rough estimation was made that if no meteorological services were available, up to 50 percent of the oil spilled could not be recovered. With this estimation it is easy to observe the economic benefit of effective oil combating in Croatia if enabled by good meteorological services. For example in a case of about 10 000 litres spilled oil to the Croatian sea area the benefit can be evaluated to be up to 205 000 € (5000 *l* × 41 €/*l*).

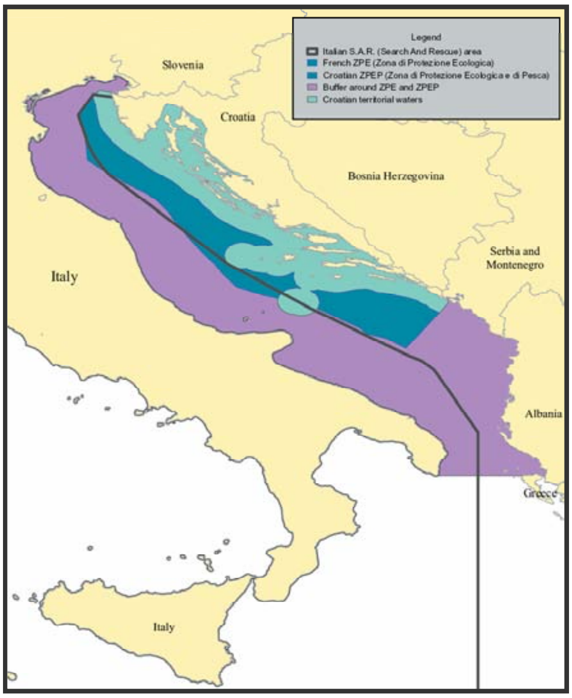


Figure 12. Special areas around Italy (Tarchi et al. 2006).

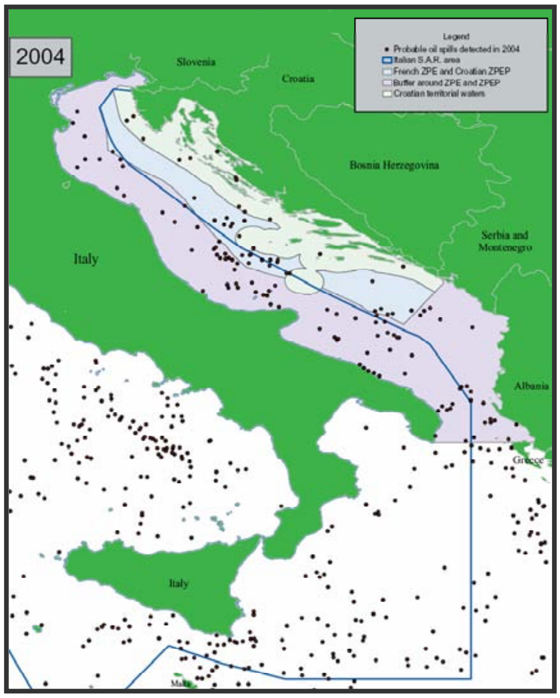


Figure 13. Probable oil spill detected around Italy in 2004 (Tarchi et al. 2006).

River traffic

In Croatia river traffic may develop to a significant transport mode in the future. Thus the benefits described in this chapter are all potential benefits. For the use of inland waterways information such as water level, precipitation and "agrohydrology" is needed. The importance of the development of inland waterway transportation is highlighted as it is energy efficient, quiet and relieves the congestion on roads.

According to expert judgement in Croatia (VTT 2006c), significant new inland waterway systems are being developed:

- new channel to connect rivers Danube and Sava; with river Rein, Danube creates a waterway from the North Sea to the Black Sea and the new channel connects Croatia to this waterway.
- new port to Zagreb by the Sava river; when the above mentioned channel is built and Zagreb is connected to the European inland waterway network, the new port of Zagreb can serve as an important inland port.

Inland waterway traffic needs a variety of meteorological services. With the development of the new economically important Croatian inland waterways, special meteorological services could be provided by DHMZ for the different needs of the increasing river traffic. Information on water level, precipitation, irrigation, etc. is an example of such information.

Boating and other recreational use of water areas

Boating is a significant industry in Croatia, both for tourist and local people. As mentioned earlier in January 2005 there were 102 916 fishing and recreational boats registered in Croatia. During the summer of the same year there were approximately 200 000 movements of boats in Croatian waters. (VTT 2006a)

It is obvious that boating gains significant benefits from meteorological services e.g. people can avoid dangerous weathers and plan their trips well in advance. However, the present meteorological services are not accurate enough. The Croatian coast area needs to be divided into smaller forecast areas where more accurate local forecasts and warnings are provided to the customers.

New, more accurate services can also enable increased number of boating days for tourists and local people. With the local forecasts, DHMZ shall also be able to provide services for organisations (marinas, magazines, yacht clubs, etc.) that sell this specialised meteorological information to their clients, for example tourist boating services. In addition the provision of accurate information benefits professional and recreational fishing.

Tourism

Tourists enjoy different waters activities (diving, boating, waterskiing, etc.) some of which have already been referred to in the previous chapters. The safety of the tourists is an important issue for the companies selling services to tourists and to the Croatian tourism industry in general. To assess the potential benefits for tourism it should be evaluated what water activities are offered in Croatian tourist resorts and which of these can benefit from the use of special meteorological services. These services enhance the safety and quality of tourism services.

As mentioned in chapter 1.4.1 (Basic meteorological services) at present meteorological information is provided to tourists on TV, radio, newspapers, etc. but the problem is how to encourage tourists boating in Croatia to use the services. When developing new services these issues should also be considered.

Fishing and fisheries

Fishing is not a significant industry in Croatia today. However, there is potential as the industry is stronger in neighbouring countries and may also grow in Croatia. As mentioned in chapter 2.1.6 (Tourism), in addition to professional fishing, meteorological information services are also needed by recreational and private fishing. The services should be developed to increase safety, comfort and efficiency of fishing.

4.3.5 Conclusions on the evaluation of the benefits

Potential impact table

The evaluation of benefits gained by providing different DHMZ services, i.e. forecasts, climate scenarios and historical trends, was the starting point of this analysis. It was noted that the main benefits are generated by the nowcasting and warning services, daily forecasts and medium term forecasts as the services for season forecasts, climate scenarios and history and climatological impacts were either not provided or not evaluated to have an impact (marked with **X**, Table 8). The benefits of services were identified in areas of safety, environment, material damage reduction and operating economy.

Table 8. Current meteorological services (general weather forecasts and maritime weather forecasts and warnings) used by different maritime actors and their impacting on safety, environment, materials consumption and economy issues.

	History and climatological impacts	Nowcasting and warning services (0h–12h)	Daily forecasts (12h–24h)	Daily forecasts (24h–3d)	Medium term forecasts (4d–10d)	Season forecasts (1–6 m)	Climate scenarios
Safety of human lives		X	X	X	X		
Environment		X	X	X			
Materials		X	X	X			
Economy		X	X	X	X		

One of the activities for which the economic benefits were impossible to evaluate, based on Croatian statistics or even expert judgement, was the search and rescue (SAR) activities. In Croatia a new law on the SAR activities has been drafted. This law shall provide requirements for DHMZ since it includes description on the use of meteorological information for SAR purposes. The date of enforcement of this law was not known during the drafting of this analysis. In the light of the research done in other parts of the world the future services of DHMZ will undoubtedly provide significant benefits for organised SAR activities. The efforts of DHMZ during 2005 and 2006 have somewhat concentred on the fulfilling of EU requirements.

In addition to services provided to mariners, shipping companies and other maritime actors, DHMZ marine meteorology in Split also provides information to the military, i.e. to the Croatian Navy. The enhancement of this service is one of the future development targets.

Summary of potential economic benefits

Sufficient amount of information for the estimation of comprehensive economic benefits of DHMZ services was not available. Many of the related organisations do not compile statistics and some of the activities under consideration are handled by several organisations, making it very difficult to evaluate the total impact of services. The aggregate maritime activities that are estimated to benefit the most from the meteorological information services are shown in Table 9 together with estimated benefits. As the Croatian case analysis was largely conducted relying on the Finnish case analysis conducted earlier, the corresponding figures from Finland are shown in the middle column.

Table 9. Summary of estimated benefits of DHMZ information services to maritime industry derived from corresponding Finnish estimations.

Key figure	Finland	Croatia
Number of boats	420 000 [1)]	**200 000**
Annual number of boating accidents at sea	700	**1 000**
Fatalities in weather related accidents	–	**3–7**
Fatalities saved due to delivered met-information	10–20	**5–10** [2)]
VOSLs per annum	17.5–35.0 million €	**3.6–7.2 million €**
Number of rescue missions avoided	34	**17**
Savings in rescue mission costs per annum	0.24 million €	**0.05 million €** [3)]
Number of port calls	44 988	**5 806**
Planning and conducting of oil combating pa	12.1 million €	**0.64 million €**
Total benefits pa		**4.3–7.9 million €**

1) The number of all boats in Finland (including boats without motor) is approximately 737 000.

2) The number of boats in Croatia is approximately 50 % of the (motor) boats registered in Finland but the annual boating season in Finland is on average 4–5 months wheras in Croatia the weather enables boating all year round. In Finland boating is mainly done with one's own boat in fairly familiar waters and conditions whereas in Croatia, boating tourism includes rented boats and are therefore used by people unfamiliar with the waters, which is very popular. Based on this information it is (conservatively) assumed that the number of fatalities saved with the utilisation of meteorological services is about half of the lives saved in Finland and multiplying the Finnish value of statistical life (VOSL) with Price Level Coefficient 0.41: e.g. 17.5 million € × 0.5 × 0.41 = 3.59 million €.

3) The number of rescue missions avoided with the use of meteorological services is expected to be half of the corresponding figure in Finland as was the number of lives saved. Then the monetary value of rescue mission savings is multiplied with the PLC: 0.5 × 0.41 × 0.24 M€ = 0.049 M€.

4) Year 2004 was the reference year for number of port calls. During this year there were altogether 204 362 port calls in Croatia of which the great majority was made by vessels in domestic traffic and only 5806 by foreign vessels. Most of the domestic vessels are small vessels travelling between the islands and main land. Though these vessels may naturally also cause oil pollution, the major accidents are caused by tankers and larger vessels with a lot of bunker fuel. Also the larger vessels use environmentally more dangerous heavy fuel oil whereas the smaller vessels often run with light fuel oil. To make conservative assumptions, only the number of foreign traffic vessels was chosen to represent the potential for oil pollution. The benefit of meteorological information was evaluated from Finnish value of benefit. First the monetary benefit calculated in Finland was divided with number of port calls. This number was then multiplied with PLC and then multiplied with the number of foreign vessels port calls in Croatia: 267 €/port call × 0.41 × 5806 port calls = 0.64 M€.

The reference study on Finnish Meteorological Institute included evaluations of more activities than those shown in the Table 9. A list summarising those activities for which economic benefits could be evaluated is shown in Table 10.

Table 10. Economic benefits of meteorological information services in Finland and the share of Finnish Meteorological Institute of the total benefit.

Personal safety	**Economic benefits**
Improved safety of boating and recreational use of water areas	
- reduction of accidents	
- reduction of accidents with personal injuries	17.5–35.04
Fatigue prevention (SAR personnel and ship crews)	
Anticipation and prevention of threats to personal safety (passengers, SAR personnel and ship crews)	
Environment	
Planning and conducting of oil combating	12.10
Estimation of the spread of dangerous goods in accident situations	
Material	
Prevention of damage to materials	0.10
- damages to equipment and hull	
- planning and execution of salvage operations	
Economic	
Savings in SAR operation costs resulting from the reduced number of accidents	0.24
Evaluation of required human resources, facilities, equipment and material	
Planning and scheduling of transportation routes	
- route planning for single passage	
- fleet transportation routes	
- speed optimisation	
- reduced bunker consumption (single passage)	0.9
Planning and execution of icebreaking services	
Marketing of sea voyages (passenger vessels seasonal traffic)	
Prevention of costs and penalties of delays in scheduled traffic or tramp shipping (breach of contract, planning of chartering agreements)	0.07
Economic benefits in total	30.9–48.5
Share of Finnish Meteorological Institute of the production of meteorological services to maritime traffic	80%
Million €	24.70–38.8

DHMZ Maritime services future development

Several development ideas and future opportunities for DHMZ were identified during this work. The main goal of the DHMZ in the field of maritime services is to build a Centre of Excellence (COE) of maritime meteorology in the eastern part of the Adriatic Sea to be able to realise the ideas and respond to the opportunities. The Centre of Excellence could be located in Split where the present centre already provides many services. However, to achieve the goal, both the content of the services and the area covered with these services needs to be broadened. In addition, this COE should have extensive knowledge on the whole Adriatic Sea area. In the future it could also provide forecasts for the whole eastern Adriatic Sea.

In brief, the Split marine service unit is not able to meet the modern requirements for producing information to the shipping industry. The services aimed at maritime sector need to be developed both in terms of volume and quality. This necessitates the employment of highly educated personnel and the acquiring of modern technical tools for these personnel. At the moment the lack of capacity in knowledge and technology is hampering the operation. The key to the future service is to provide accurate local area information meeting the requirements.

In light of the DHMZ development and ensuring quality meteorological services, it is important that the government of Croatia fully understands the significance of maintaining and further developing the Croatian meteorological services, including the maritime services. As an important part of the DHMZ operation both the technological and organisational aspects of DHMZ operation should be developed aggressively. Among many other things this means that the Split maritime services should be more strongly connected to the central part of the service in Zagreb. To create a basis for the Centre of Excellence in maritime service i.e. the foundation for efficient and professional work, more highly educated experts in meteorology and integrated IT are needed. One fundamental precondition for the DHMZ development is also the moving of both Zagreb and Split operations to premises that fulfil the requirements set by the technical demands of DHMZ operation.

4.4 Aviation

4.4.1 Introduction

Even though meteorological services for aviation are currently not DHMZ's responsibility, a simple assessment of the impacts of met-information services for aviation can be done. The following estimate is based on international evidence and statistics, and some details have been computed in relation to the evaluation of the Finnish Meteorological Institute. As the overall economic development of Croatia affects also the aviation sector, available statistics do not give a clear picture of volumes and safety of the sector. Therefore, a word of caution is in place with regard the interpretation of the following estimates.

4.4.2 Methods

Based on the information that was available there are two main methods that can be incorporated. Fuel savings were calculated with the model estimated on data from a sample of Finnish flight plans and potential savings (Hautala et al. 2007). Accident cost savings as well as airfield maintenance cost savings were estimated using Finnish and international statistics and scaling the impacts to the Croatian statistics, mainly using the ratios between the volumes of different operations.

There are two main reasons behind fuel savings when utilising meteorological information. The first is the possibility to find a better situated alternate airport, and this way to avoid extra fuel load – this is not unusual in exceptional situations when the planned arrival airport is unavailable (because of technical reasons, weather, etc). The second is the possibility to find tail winds for long distance flights. It was assumed that these savings are utilised in the same way as in Finland, taking into account the length distribution of the flights, i.e. the longer the flights, the more savings there are to be gained.

4.4.3 Main impacts

The main impacts of meteorological services for aviation are improved safety and higher reliability. It was assumed that aviation safety and the safety trends are at the same level in Croatia as in other European countries, even though the statistics for scheduled and charter flights gave a slightly worse picture of the situation. The estimate is based on the yearly number of departures and aircraft-km per year and the same share of weather related accidents as was available in international statistics. Accident savings due to weather information services were roughly estimated to be 5 million € per year.

For airline operators accurate, up-to-date weather information and forecasts offer possibility for fuel savings, as flight altitude, routes, and alternate airports may be fine-tuned with wind and weather conditions in mind. Calculations are based on typical savings for different lengths of flights. The savings in fuel consumption are about 1 million € per year, if operators are able to take full advantage of the meteorological information they receive.

Better safety is also a major benefit resulting from meteorological information provided for general and military aviation. In addition, benefits may also be found in the planning of operations. There was not enough detailed data available to estimate the aforementioned benefits appropriately, but their role will grow in the near future in pace with the growth of Croatian economy. The current safety situation of both commercial and general aviation in Croatia is somewhat worse than in Europe in general, so the potential of safety increase is assumed to be significant: at least 6 million € per year with current volumes.

Other impacts may be found in maintenance of airports (planning of maintenance operations), time savings of passengers, and environmental impacts. Of these potential benefits only the reduction in CO_2 emissions was estimated. The monetary value of theses savings is up to 0.2 million € per year.

4.5 Building construction, infrastructure and facilities management

4.5.1 Introduction

State-of-the-art

The building stock in Croatia is dualistic – partly very old and partly quite new. According to the representatives of DHMZ there are no large domestic contractors who could utilize detailed meteorological information. Therefore the demand for meteorological data by the contractors and building stock owners is presently considered to be somewhat low.

The value of building stock in Croatia relative to the total national wealth is unknown. In Finland the value of building stock today is about 260 billion € and it represents 50% of the national wealth. Also the future economic growth in Croatia is uncertain and depends on multiple parameters. The most important parameter is the full membership to the EU which will most likely boost the growth. However, a part of the growth potential has already been realised.

DHMZ's service products for contractors and facility owners

Currently there are no tailor-made meteorological or hydrological information service products for builders and facility owners. The contractors, however, use normal public weather reports. The situation in Finland today is almost the same. The reliability of weather reports is good enough for standard construction projects and facility management process.

4.5.2 Construction in Croatia during 2005 and onwards

In reference to Finpro (2006) the following facts on Croatian building industry are reported:

- The amount of new construction was slightly decreased between 2005 and 2004; this means that this market from the viewpoint of DHMZ's services is not necessarily a "high growth market" but rather "a stable expansion opportunity".
- From the total output of construction 1/3 was building construction and 2/3 infrastructure; this implies that large infrastructure projects which in many cases involve large international contractors can be just as lucrative customers as building contractors.
- The housing construction volume in 2004 in Croatia was 4 994 dwellings and the total floor area was 297 620 m^2, in Finland during the same year housing construction was over 32 000 dwellings.

Comparing with Finland the profile of construction is very different. In Finland building construction covers 80% and infrastructure 20% of the total construction. According to the relationship in housing construction between Croatia and Finland, the total value of construction in Croatia is about 1/7 of that in Finland. However, it is assumable that the volume will more likely to be increasing than decreasing, because of the fast development pace wittnessed in Croatia. Aggregate economic growth will always have a direct impact on construction.

Building construction / GDP in Croatia is annually 5–6% (in Finland the corresponding figure is 5%). This means that total value is 1 500–1 700 million € per year.

Statistics concerning facility management are not available. The situation in Finland is almost the same. The value of building-related services, of which facility management is the most important, is in Finland one billion € per year. In Croatia, the relative importance of building-related services is smaller and is estimated to be between 50–100 million € per year.

In the medium and short term, the fastest growth is in road construction. Weather information services are very important, for example in asphalt work, but also foundation works for substructures, bridge construction works and excavation works include weather-sensitive phases. These works are also a part of any major infrastructure project, such as rail or port construction projects.

The growth of national wealth is increasing quite rapidly in Croatia. It can be anticipated that the interest of international contractors in Croatian markets is already there. This gives new possibilities for DHMZ to develop products for the construction sector.

4.5.3 Conclusion

As it stands today and probably also in the near future, DHMZ does not consider construction and building sector a very potential user of meteorological service products. However, in the future the demand will surely grow as contractors gain awareness on the benefits of efficient weather information utilisation. From the contractors' point of view, these services have the potential to enhance the efficiency and smoothness of their construction process. Other weather warnings (e.g. Bora-winds) might be potential services for contractors. These warnings would improve safety on construction sites and reduce harmful incidents and accidents and thus directly improve the profitability of the projects in addition to savings in human and material damages.

Table 11 shows the value of additional construction costs caused by unfavourable weather, such as heavy rainfall, snow or strong winds. The problem with the estimates is that no clear-cut statistics were available for the analysis. However, taking into account the climatological differences between Croatia and Finland and the differences between volumes of the construction, a very rough assessment on the potential savings can be done.

Table 11. The estimated value of additional construction costs caused by unfavourable weather conditions and the estimated savings potential with improved weather information utilisation.

	Additional costs (million € /a)	Potential savings with better information utilisation (million € /a)	Note
Building construction	20–30	0.3	Only direct costs estimated, and thus the potential for savings also including indirect weather-resulted costs are an additional savings potential.
Infrastructure	50–70	0.6	
Facility management	50–100	0.4	

The ultimate potential for savings for weather-prone construction costs including both direct (mostly *in situ*) and indirect (e.g. damages that appear years after the exposure to unfavourable weather) is estimated to be around 1% of the direct additional costs caused by weather. Thus, the full potential is around 1.5 million €/a. The current benefits are estimated to be around 0.5 million €/a. which is relatively slightly less than in Finland.

It is recommended that a better understanding on the weather-related risks in construction is pursued. As the construction activity is most likely to grow and international contractors also step in to the market, there are good opportunities to offer such services to contractors that help them to improve their operational performance in projects and the sustainable quality of their delivered products.

4.6 Energy production and air quality

4.6.1 The Croatian energy sector

The privatisation of Croatian energy sector is ongoing while drafting this analysis. At present, the government-owned energy company Hrvatske Elektroprivreda (HEP) has a monopoly in electricity production. However, HEP's own power production is not enough to meet the total power demand in Croatia, and hence Croatia is importing about 17% of their electricity from the neighbouring countries. HEP owns and operates 25 hydro power plants, four central heating plants, and three combined heat and power plants (HEP 2006).

The situation is quite similar in the oil and gas sector. Industrija Nafta (INA), of which the majority is owned by the government, is responsible for the oil and gas production with its two oil refineries in Sisak and Rijeka. INA also owns over 400 petrol distribution stations. About half of all oil and gas is imported, mainly from Russia. A new oil pipe (Druzhba) from Russia has been under planning for several years now, but it is still not fully accepted because of environmental grounds. The Croatian oil pipe network is operated and owned by another large governmental company Jadranski Naftovod (JANAF).

The main challenge for the Croatian energy sector is to privatise these large state-owned energy entities. Furthermore, achieving a steady position in oil and gas transportation from Eastern Europe and Asia to Europe is a major challenge and opportunity at the same time.

4.6.2 The meteorological and hydrological services needed in energy (electricity) sector

Extensive weather information is needed when power plants and electricity grids are operated optimally and as planned. Security of supply is the priority in energy production and distribution. Reliability is even more important thinking of industrial customers and their production facilities. Even short power failures could harm the industrial activity and are extremely costly. Energy producers have to foresee possible threats that changing weather conditions may cause.

The use of tailor-made meteorological and hydrological services (forecasts, warnings etc.) is one of the key means to control the impacts of changing weather conditions and keep the electricity grid stabilised at all times. The main problems created by exceptional weather conditions in the Croatian electricity supply according to HEP are as follows:

- power supply failures
- damage to buildings and plants
- non-completion of planned work and generation shortfalls
- increase in maintenance costs for buildings and plants
- increased energy consumption
- overflows.

According to HEP, the main impacts of these problems caused by weather conditions are the following:

- interruptions in electricity supply to industry, households and other consumers
- destruction of the transmission network (towers/lines) due to wind/ice
- lock-out of switches and puncture of insulation caused by salt sediments on cross-island connections and in the littoral part
- damage to embankments and rock-fill dams caused by ice and waves as a result of prolonged low temperatures and strong winds
- drought/flooding have adverse impact on the implementation of generation plans, i.e. the pace of completion of works related to the construction and maintenance of plants.

Monetary values of these impacts have not been explicitly specified. However, they are included in damages caused by natural disasters, which have been for HEP as follows:

- year 2001: HRK 14.2 M (1.945 million €)
- year 2002: HRK 11.5 M (1.575 million €)
- year 2003: HRK 22 M (3.013 million €).

These costs could be reduced by additional weather/hydrological information services that would help HEP to overcome such damages. These are for example:

- precipitation, wind and air temperature forecasts for plant locations
- communication on expected extraordinary meteorological and hydrological conditions for the next 1–3 days
- season weather forecasts
- on-line hydrological data
- availability of historical meteorological data
- hydrological forecasts.

There are probably some additional information services than those listed above that could be helpful, but such innovative information services should be offered to HEP by DHMZ. According to HEP, prompt and efficiently submitted weather services that enable HEP to reduce potential damages would certainly be paid for and become part of continuous business relations with DHMZ.

For the time being HEP uses meteorological and hydrological services worth approximately 1 million € per year. The benefits achieved by utilizing the services exceed this worth. Even if detailed cost/benefit analyses have not been conducted, it is presumed that the ratio is well on the positive side (see Table 12).

For example, on the basis of the study in Finland focusing on the services provided by the Finnish Meteorological Institute (FMI) (Hautala et al. 2007), the benefits of weather information services for energy sector covered at least three times the cost of the services.

Table 12. The main benefits for energy sector; the annualised values are very rough estimates because of the lack of precise data.

Industry / Sector	**Main impact mechanisms**	**Main benefits**	**Current annualised Value**
Energy production (provided already)	Energy production forecasts (operation control); Security of supply (operation, maintenance, damage prevention); Infrastructure (electricity grids); Hydro power (dam controlling, overflows);	Prediction of power demands; Power failure reduction; Savings in material (damages) and working time (repairing, maintenance costs); Prevention of damage to buildings and plants; Avoiding generation shortfalls and overflows; Energy savings	1. Electricity production: – savings in maintenance costs (power failure prevention and repairing) : ca. 1–2 million €/a, – operation (power demand prediction, energy savings): min. 1 million €/a, – other benefits: unknown Electricity total: min. 2 million €/a; in future growing 2. Other energy (heating plants, oil and gas production etc.): unknown
Air quality monitoring and warnings (in the future)	Air quality forecasts and warnings (in future); Health impacts (fine particles causing pulmonary diseases and deaths)	Reducing adverse health impacts; Saving human lives in possible environmental accidents (evacuations)	3. Air quality (dispersion models): significant potential, very useful for the authorities

4.6.3 Some recommendations for the energy sector

According to the results of this analysis and our previous case studies, it seems to be very beneficial to develop some tailor-made weather and hydrological services by DHMZ for the energy sector. Some examples of these could be:

- “energy weather” service (for different time-scales from 12 h warnings to one month or seasonal forecasts); especially 1–3 day warnings and forecasts
- storm/thunder/lightning warnings
- on-line hydrological data and flood warnings (these are already provided by DHMZ).

In addition, there are also some small companies dealing with independent energy production (e.g. AdriaWind Power and some small hydro power plants), which are probably using some weather forecasts, but not in a constant and systematic way. These companies will need specifically tailor-made forecasts and specific warnings that could be developed and provided by DHMZ.

As the energy market is further liberalised, the expected short-term changes (e.g. 1–10 d) in the production capacity (e.g. due to wind speed for wind power or rainfall for hydro power) will be valuable information to energy traders and brokers. The same applies to the demand side, i.e. how much is the anticipated electricity consumption due to e.g. colder or warmer weather.

4.6.4 Air quality

Environmental and health impacts of polluted air can also be reduced (including environmental accidents) with reliable and well-timed weather information, by measuring air quality and by using e.g. dispersion models for predicting the transportation of emissions. Air quality forecasts and warnings could be further developed in the near future by DHMZ to reduce adverse health impacts (e.g. fine particles cause pulmonary diseases and deaths especially for asthmatics and older people). Especially, in the case of possible serious environmental accidents the possible evacuations (by the National Protection and Rescue Directorate) could be done with the help of real-time dispersion models thus saving human lives in critical situations.

4.7 Agricultural production

4.7.1 Introduction

The most weather prone sector in our societies is agriculture. Land use, crop selection, and farming practices are all directly dependent on the prevailing local climate. Major parts of the farming produce are very vulnerable for unfavourable weather conditions and thus the value of meteorological information can be considered significant. Climate variability and climate change have large impacts in crop growth and development, crop yields, and activities such as shift in cropping periods, crop rotations, and modifications of cropping systems. We are facing new threats through deforestation, wind erosion and water erosion, more agricultural use of sloping lands, migration into vulnerable areas, and new insect pests. Climate variability and change, in all contexts, represents a factor of risk, which can have the dimensions of disaster in fragile and more vulnerable environments. Agro-meteorology can help us to cope with these environmental hazards and mitigate their negative impacts.

4.7.2 Agriculture in Croatia

Croatian agriculture is dominated by small family farms. Approximately one third of all farms are 1 ha in size or smaller and about one half of the farms are between 1 and 5 ha in size. Less than 3000 farms have a size greater than 20 ha. Most important crops are maize, grapes, wheat, potatoes, sugar beet and soybeans. Other important crops are tobacco, tomatoes, apples, olives and cabbage. Most important products of animal husbandry are milk, eggs, pork and chicken. The majority of the farming products are very vulnerable for unfavourable weather conditions.

4.7.3 The importance of weather services to agriculture

Given the fact that weather affects every stage of farming activities in one way or another, the benefits gained by the specialized weather forecasts for farmers are quite obvious. The benefits may be direct economic savings in production costs for instance through preventing crop losses by sprayings. Reliable and frequently updated weather forecasts make also decision-making on farming activities and planning of these activities significantly easier.

At the beginning of the growing season correct timing of sowing is essential for the yield of spring grain. Successful plant protection of spring cereals and sugar beet calls for exact and correct timing. Five-day weather forecasts are then of crucial importance for work planning; the time of e.g. surface harrowing is vitally dependant on the rain, air temperature and air humidity expected. In the dry early summers, irrigation results in a substantial increase in yield as well as an improvement in the quality of yield. Reliable weather forecasts are also crucial for the quality and quantity of the yield during harvesting.

Agro-meteorological services are provided by the Meteorological and Hydrological Service of Croatia (DHMZ) as a part of their daily service. This service includes meteorological information given on radio, television and in daily newspapers. Meteorological services for agriculture are also available on Internet web sites maintained by DHMZ (*http://meteo.hr*).

The meteorological information is needed to guarantee that the agricultural production is as effective as possible and to ensure high quality of agricultural products. The benefits that can be gained by effective agro-meteorological services encourage to maintain and to further develop these services. An effective use of meteorological information helps to optimize the use of fertilizers and pesticides, which benefits in lower costs for farmers and it also has highly favourable effects on environmental protection too.

4.7.4 Methods to estimate the importance of meteorological services

Various methods have been used for measuring the economic benefits of meteorological services. For instance Freebairn and Zillman (2002a and 2000b) have done salient research on this area and they have analyzed the applicability of various methodologies proposed for measuring the economic benefits of meteorological services. According to Gunasekera (2003) there is not just one method of assessing the economic value of meteorological services.

Market prices can be used as a measure of the marginal benefits to users of meteorological information. An advantage of market prices is that they explicitly reveal the value users place on, and are willing to pay for, particular categories of meteorological information (Freebairn and Zillman 2002a).

The most commonly used techniques to estimate the value of meteorological information are normative or prescriptive models. The approach in these models is to view meteorological information as a factor in the decision-making process that can be used by decision-makers to reduce uncertainty. This approach is based on Bayesian decision theory (Johnson and Holt 1997).

The contingent valuation method is based on survey techniques and hypothetical situations to elicit users' "willingness to pay" or their "willingness to accept" for hypothetical changes in the quantity of non-market goods such as public weather information (Mitchell and Carson 1989). Conjoint analysis is a method which has been used extensively in marketing and transportation research (Lazo and Chestnut 2002). It has been used increasingly in recent years, including the evaluation of meteorological information.

4.7.5 Earlier studies

The UK Met Office has increased the economic benefit to the user by providing a package of weather information tailored to their business activities. They have shown that understanding of the market place and business practice is essential to those who provide meteorological information. In the process of increasing benefits, industry must also be educated in the need to use weather information in the decision-making process. Studies by Met Office have provided information on quantitative benefits for specific services. For example one of the companies had estimated potential annual savings from meteorological service to be in the order of £700 000, with a benefit-cost ratio of about 30. The studies have also shown the importance of qualitative benefits to industry. Most participants in the study perceived the main benefits as being the usefulness of the forecast in supporting and aiding management planning (Ballentine 1994).

A research study of enhanced cottonfields weather service was carried out 1997 in Australia. The analysis of this survey revealed that annual gross benefits were about A$397 150 for cotton production only. The total annual costs incurred by cotton producers for the use of the service were A$31590. Hence the benefit–cost ratio of this specialized weather service was 12.6 (Anaman et al. 1997). The majority of the users of this weather service indicated that it provided them with some non-financial benefits too. About one third of the users reported that the service assisted them in their general household planning and decision making. Planning of outdoor and recreational activities was identified as the second most important non-financial benefit of the service.

In Finland a survey research was carried out during the development of farmers' weather service. (Ansalehto et al. 1985). This study was carried out in 1983–1984 in Southern Finland; 230 farmers participated in this study. Farmers were offered weather forecasts specifically tailored to agricultural purposes through an automatic answering machine five days a week from May to September during the research period. Farmers were presumed to be able to make good use of the specialized meteorological information on their own and they were not given any training for utilization of the meteorological information. The evaluation of the research was done by questionnaires mailed to the farmers participating in the project. The study revealed that it was very difficult for many farmers themselves to assess the amount of the economic benefit gained from the specialized meteorological services. The economic benefits were then summed up from the assessments made by the farmers with the help of agro-meteorologic experts. Results of the study revealed that the economic added value benefits given by the specialized weather services (taking into account the change in the cost-of-living index from 1984) during 2006 in Finland for the main sectors of farming activities were:

◆ sowing	12 million € / a
◆ spraying and protection	8 million € / a
◆ harvesting	12 million € / a
◆ other actions	2 million € / a
Total	34 million € / a.

4.7.6 Estimate of economic benefits gained by agro-meteorological services in Croatia

To be able to estimate potentials in the added value economic benefits of specialized meteorological services in Croatia we have used the results found in the Finnish study as a template for our assessment. In this conversion of Finnish results into Croatia we take into account exclusively the total economic benefit in Finland because the structures of agriculture in Finland and Croatia are not directly comparable. We assume that the benefits of well organized agro-meteorological services in Finland are 34 million €/year. The value of agricultural production in Finland is 6 876 million US$ (2004) and in Croatia 3 030 million US$ (2004)[14]). If we take the ratio of Croatian and Finnish agricultural production and multiply it with the Finnish total benefits figure, we end up with a figure **15 million €/year.** This figure may be considered an estimate for the distant future objective of added value economic benefits gained by well organized meteorological services in Croatia. In the near future a more realistic figure should be about 5–10 million €.

The costs caused by unfavourable weather conditions on agriculture are also substantial. Thus there lies a potential for additional economic benefits through enhanced weather forecasts in preventing at least partially the damage caused by hail, frost, drought and floods. The costs for damage caused by these unfavourable weather events in Croatia are annually on an average (avg. 1995–2005):

[14] *http://global.finland.fi/public/default.aspx?nodeid=32367&contentlan=1&culture=fi-FI*

- hail 42.7 million € / a
- frost 16.5 million € / a
- drought 50.6 million € / a
- floods 19.8 million € / a.

4.7.7 Closing remarks and recommendations

It is recognised that there is some awareness of the impact that National Weather Service (NWS) can bear upon various elements that contribute to socio-economic well-being, through the provision of information, products and services. However, what appears to be lacking is a clear and precise understanding of this impact. There is a need to provide quantitative assessments of this impact. This could be considered as one of the urgent tasks of the NWSs, as well as those who collaborate with the role of NWSs, such as the national planning offices. This can lead to an even greater appreciation of their role, a better definition of their capability, a consequently greater possibility of additional resources for the strengthening of the national meteorological services, and increase benefit to society.

The estimates presented in this report are of preliminary nature, taking into account the information available.

5. Results aggregated

5.1 Benefits generated by the met-information services

The total benefits generated annually by current information and "perfect" information, as far as the analysed sectors are concerned, are aggregated in Table 13 Transport was in the focus of the analysis in the sense that all relevant modes were studied separately.

Table 13. Aggregated results on benefits generated by the day-to-day services of DHMZ.

Sector / Industry	Total benefits per year with current information (= current benefits) (million €/a)	Total benefits per year with perfect information (= potential benefits) (million €/a)	Notes
Transport			
-road	3.1–6.2	5–10	Main benefits in road safety and operational road maintenance
-rail	not assessed	0.15	Main benefits from time savings and track maintenance
-maritime and inland waterways	4.3–7.9	not assessed	
-aviation	12.2	15	Main benefits accrue from enhanced safety; because of already advanced services, the difference between current and potential benefits is not very significant
Construction and facilities management	0.5	1.5	Main benefits from *in situ* operations and long term damage prevention
Energy production and distribution	2.0	not assessed	Maintenance and operation of production plants and grid lines
Agriculture	5–10	15	Main benefits come from reduction of crop losses
Total for the analysed sectors	*27–39*	*37–42*	

5.2 Additional benefits not included in the calculus

During and even before the study, it was apparent that many sectors and thus many benefits, especially those generated by current information services, were excluded because of pragmatic reasons. One of these crucial industries was *tourism*, which has been heavily increasing in Croatia during the past few years. About 6% of the country's work force is employed directly by tourism and indirectly the importance is even beyond that (Finpro 2006). Between 2004 and 2005 the growth of Finnish travellers alone was 42%. Personalised weather information services for sailing, hiking, and various types of outdoor activities could well offer new business potential for DHMZ. Travel agencies should be very interested in providing such services on a value-added basis to their customers.

Logistics is one of the key beneficiaries of meteorological and hydrological information services. Warehousing, supply chain management and physical transport are all functions that could utilise meteorological information much more. This was shown in the Finnish case study (Hautala et al. 2007). Original work plan included the analysis on logistics but due to the lack of adequate data and information the analysis was not possible.

Civil protection and rescue activities are already today using meteorological and hydrological information in the planning and carry-out of their operations. Historical data is very important for the planners in order to assess risks and create likely threat scenarios caused by weather. Short-term and nowcasting are obvious for operative activities in the field, but no less important. During the workshops the experts and managers of civil protection and rescue indicated on many occasions the existing vital needs for hydrological and meteorological information as well as the great potential there is for future information services. The main bottleneck in full-scale utilisation is not the actual quality or quantity of information but rather the managerial and working processes which need to be developed so that information can be maximally exploited. Evidently, a great socio-economic benefit potential lies here.

5.3 Benefit-cost assessment of DHMZ

If we assume that the annual budget of DHMZ is about 8 million € per year, **we can estimate that the services delivered by DHMZ pay themselves back at least 3-fold each year, this estimate being a conservative one. Taking into account all the excluded sectors, the authors' conclusion is that DHMZ's services generate today an annual benefit which is about five times its budget**. By improving the services, especially their deliverance, the potential ratio between annual costs and benefits is about 4–5 looking only at analysed sectors, and correspondingly we can expect that with a full range of services (i.e. including all beneficiary sectors) the future benefit potential could lie somewhere in the range of 6–10. This potential can be thought to also include the disaster prevention benefits, which were completely excluded from this study. Naturally, the ratios are an expert assessment of the authors, but they seem to be somewhat in line with other research results, e.g. Anaman et al. 1997.

The results are also in line with the Finnish case study on Finnish Meteorological Institute's benefits, but since the Croatian ratios heavily relied on Finnish benchmarks, this is only a natural outcome. However, we must keep in mind that the annual budgets of the two institutes are in principle independent from each other, we still obtain ratios of similar magnitude.

5.4 Future services and service product development

In Table 14, the existing and to-be-developed service is mapped. The benefit generating potential of the services is assessed too. The table is based on workshop results and thus represents the views of the workshop participants. The matching of critical and highly beneficial services along with to-be-developed services deserves the upmost attention. It should also be noted that "no impact identified" does not necessarily mean that there is no impact.

5.5 Investments in physical and human capital – the way to realise potential benefits

The assessment on investment needs was done on the basis of several fact-finding missions to Croatia. Partly these missions were carried out in conjunction with workshops and partly independently.

The most urgent investment needs are targeted at the following areas:

1. Observation infrastructure – the infrastructure needs to be updated to meet the demand of more advanced services. Namely the biggest needs are investments in radars and lightning detection systems as well as in automated observation stations.
2. Service process – the process from observations to services and products can be further automated and enhanced in a way that allows more tailor-made products. Automated products can be distributed to mass-media and the consumer market, whereas the tailored services can be targeted according to the needs of the corporate market. Investments are mainly software products and training of professionals.
3. Know-how of the organisation – investments in human capital needed to ensure that skilled professionals are at the disposal of DHMZ. This probably also means competitive salaries and increase in the education level of the personnel.
4. Investments in the facilities of DHMZ – the current headquarters is in inadequate shape and needs to be modernised or new premises must be arranged[15].

[15] The new premises are already under preparation during the writing of this report.

Table 14. Summary of workshop results: critical and beneficial services by utilising sector and mapping of service development needs.

Explanations		X=currently offered; D=currently offered but to be developed further; F=to be developed Red = critical service; green = highly beneficial service; yellow = beneficial service; white = no identified impact					
Product → Sector & Function ↓		Climate-logical history	Nowcasting and warning services (0–12 h)	Daily forecasts (12 h – 4 d)	Medium range forecasts (5–10 d)	Seasonal forecasts (1–6 m)	Climate scena-rios
Agriculture	Timing of sowing, harvesting, ploughing, irrigation, harrowing and de-crusting of soil surface	X	D	D	D	F	F
	Growth models, yield estimates	X	D	D	D	F	F
	Frost protection	X	X	X	D	F	
	Crop selection	X	D	D	D	F	F
	Adaptation to new cultivating conditions	D	D	D	D	F	F
Civil protection and rescue	National level disaster assessment						F
	Rescue and protection planning		D		X	X	
	Emergency centre 112 and rescue & protection operations		D	X	X		
	Information dissemination / public warnings		F	X	X		
Construction & facilities management	Construction phase (*in situ*)	X	F				
	Day-to-day facility management	X	F				
Energy	Hydro power production	X	D	F	X	F	F
Maritime transport	Search & rescue operations		X	X	X		
	Oil combating & environmental protection		X	X	X		
	Shipping operations		X	X	X		

In addition to the above investments, there is definitely a need to restructure the organisation in a way that enables a smooth production process. One possibility is to build a more service process oriented organisation to replace the current functional one. Modern quality assurance systems can be put in place more easily, when the organisation adopts a process view to its functions.

A layered view to the whole organisation is one key to successful development. Instead of ad hoc development and re-engineering measures we should look at the layers and the processes: do we have the necessary infrastructure in place? Do we have processes that efficiently utilise the information provided by the infrastructure? Does our organisation support these processes? How about our service architecture – does it extract services from the processes in a format that is appreciated by the users and market in general? Is our legal status and degree of management freedom such that it has incentives to strive for better services? Thus, the elements of organisation layers – infrastructure, organisation, management system, production process, regulatory framework, market needs and position – are in the focus of the analysis and must be synchronised with each other. This is one of the most challenging tasks of any management and any organisation.

A detailed strategy that describes the abovementioned development measures is presented in Strategic Development Plan for Croatian Hydrological and Meteorological Service (Leviäkangas et al. 2007[16]).

When the organisation, its processes and infrastructure is developed, it is possible to realise much of the unutilised potential of the hydrological and meteorological services. Our analysis has been focused on meteorological services and their impacts, but without any doubt similar benefits can be found in the field of hydrological information and hence it should be developed in conjunction with meteorological services.

[16] http://www.vtt.fi/inf/pdf/workingpapers/2007/W76.pdf

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Appendix A: Workshops

Brainstorming meeting 19.–20.6.2006 in Helsinki and Espoo

Participant name	Organisation
Nino Radetic	DHMZ
Kreso Pandzic	DHMZ
Vlasta Tutis	DHMZ
Branka Ivancan-Picek	DHMZ
Dusan Trninic	DHMZ
Mario Buljevic	Croatian Motorways
Matijas Maja	State directorate for protection and rescueing
Marja-Liisa Ahtiainen	FMI
Pekka Plathan	FMI
Mats Wiljander	FMI
Juha Kilpinen	FMI
Ari Venäläinen	FMI
Jukka Räsänen	VTT
Mikael Ohlström	VTT
Risto Öörni	VTT
Lasse Makkonen	VTT
Jarkko Lehtinen	VTT
Jorma Rytkönen	VTT
Sanna Sonninen	VTT
Martti Hekkanen	VTT
Raine Hautala	VTT
Pekka Leviäkangas	VTT
Jenni Eckhardt	VTT
Martti Mäkelä	Impact Consulting Ltd

Impact validation and benefit assessment workshop in Zagreb, 7.–8.11.2006

Participant name	Organisation
Vlasta Tutis	DHMZ
Nino Radetic	DHMZ
Borivoj Terek	DHMZ
Davor Nikolic	DHMZ
Gordana Zuccon	DHMZ
Milan Erjavec	State directorate for rescue and protection
Maja Matijas	State directorate for rescue and protection
Branko Grgic	Hrvatska Elektroprivreda (Croatian National Electricity)
Martti Mäkelä	Impact Consulting Ltd
Risto Öörni	VTT
Sanna Sonninen	VTT
Jarkko Lehtinen	VTT
Mikael Ohlström	VTT
Martti Hekkanen	VTT
Pekka Leviäkangas	VTT
Raine Hautala	VTT
Seppo Saku	FMI

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Title
Benefits of meteorological services in Croatia

Abstract
This research report looks into the benefits of hydrological and meteorological information services in Croatia. The benefits generated by the services were investigated by beneficiary sector, each sector studied by different researchers. The methods used were mainly literature reviews and statistics, expert interviews and workshops, and analytical, conceptual and qualitative model building and modeling of expected impacts. Assuming that the annual budget of DHMZ is about 8 million € per year this study concludes that the services delivered by DHMZ pay themselves back at least 3-fold each year. Taking into account all the excluded sectors, it further concluded that the factual ratio is even higher. The results seem to be in line with other research results. By improving the services, especially their deliverance, substantial additional benefits can be generated hence justifying the investments in the improvement of hydrological and meteorological services.

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