A Decision Support System for Urban Climate Change Adaptation

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Abstract
This paper gives an overview of a decision support system for scientists and city planners which shall be suitable to assess climate change effects on urban environments, and which shall enable city planners to investigate different measures to cope with potential effects of climate change. The system named SUDPLAN (Sustainable Urban Development Planner) is currently under development and the first version of the SUDPLAN software will be available when the HICSS conference is held. SUDPLAN is a project funded under the European Framework Program FP7.

1. Introduction
Environmental Information and Decision Support Systems (EDSS) are complex information systems containing complex information and performing complex workflows, that may not even be pre-defined (ad-hoc workflows). In general, these systems are composed of a number of highly heterogeneous components and tools solving a complex monitoring, analysis or decision support task. The component structure of such systems cannot really be generalized or even properly defined, because real world applications vary considerably depending on the concrete use of a concrete system. However, certain common elements are present in many systems [1,2] data management and data network components, geomatics components, decision support components, numerical simulation models and others. Even at the level of a single, stand-alone system for one single purpose, integration of data, models, visualization, analysis tools and decision support tools is often a very difficult and costly undertaking.

Today’s EDSS are very often hard wired (‘all-in one systems’), which is not astonishing, as the complexity covered by EDSS is enormous. EDSS have to deal with complex space and time related data and its representation, furthermore they are asked to transfer a multitude of data into easy to understand visualization representation having complex algorithms in the back end – all this before the actual decision support begins.

Due to the lack of standards for data interchange hard-wiring the tools and the data in one monolithic application is still a common practice. This practice makes EDSS expensive and inflexible and this is one of the main reasons why there are not more decision support systems in real use.

2. Recent trends in service infrastructures
In recent years an important trend in environmental informatics has been research and development on environmental information service infrastructures (in the case of geomatics components also called Spatial Data Infrastructures, SDI). The main driver for this research has been the practical need to overcome organizational boundaries in environmental management and to enable linking systems together which are operated by different organizations.

In Europe, for instance, the INSPIRE Directive [3] set the goal in 2007 to establish an Infrastructure for Spatial Information in the European Union. The directive obliges member states to make available relevant geographic information for the purpose of formulation, implementation, monitoring and evaluation of Community environmental policy-making and for the citizen. Furthermore, by establishing from the onset cross-sector co-ordination mechanisms, INSPIRE aims at providing access to compatible information across sectors such as environment, transport and agriculture.

INSPIRE has become a major driver for research in the area of environmental service infrastructures. This
driver has triggered research in FP6 Integrated Projects OASIS [4], ORCHESTRA [5], SANY [6], OSIRIS [7] and other to achieve the overall goal of interoperability. Projects funded through other programs contribute to the same goal, for instance SSE [8]. This research has reached a stage where generalized concepts are available, generalized architectures have been published, service specifications have been defined and service implementations become more and more available, in some cases as open source products.

At the same time, the use of established industry standards, most notably those of the Open Geospatial Consortium [9], OASIS [10] and the W3C [11], has become a dominant requirement in order to achieve interoperability amongst systems and stakeholders.

More and more customers require systems which they order to comply with these standards, and at the same time the standards evolution also drives some of the technological changes, along with the ongoing research mentioned in the previous paragraphs.

A common trend of both research and standards evolution is to compose systems in a loosely-coupled way through a service-oriented architecture (SOA).

3. Effects on EDSS development

These recent developments have dramatically changed the opportunities for EDSS development. The practice of monolithic systems, which integrate data and functionality into one system, built for this purpose only, will be replaced by flexible environments which make use of external resources (data, information and services), and which provide a framework for flexible delivery of functionality to end users. This means that the “software plumbing” (individual integration projects) for each individual EDSS will cease to exist. The vision of next generation EDSS is that of a dynamic composition of services in a SOA.

4. Climate change and urban environment

The dimensioning of urban infrastructure is typically based on a statistical calculation of historical time series data, e.g. to quantify the maximum river runoff during a 100 year period, the most intense rainfall occurring within a similar period or the risk for a combined air pollution and heat wave.

The temperature increase, changes in precipitation and air pollution levels – both expressed as yearly totals and as extreme values – and storm frequencies expected to occur during the coming decades will invalidate those historical time series analysis and call for new statistical assessments based on forecasted weather scenarios up to and beyond 2050 [12,13].

There is a need for planning tools which will make it possible for city planners to include such analysis in a simple, early and cost-effective manner. In order to make these EDSS solutions affordable, data integration, integration of models as well as integration of other services must be possible at low cost, in an optimal case in an “on-the-fly” manner.

Sustainable cities also require an integrated planning approach. They need to assess some of most important environmental factors in an early stage, in particular for applications like:

- coping with the risk for river flooding and inundations of built-up areas and other developed areas
- maximum rain intensity to be expected over sealed surfaces and for which water runoff systems must be dimensioned
- spatial distribution of air pollution, risk for extreme events and high ambient temperatures in built-up residential and work areas

The sustainability must be assured both during present and for expected future climate scenarios, as simulated by regional climate models (RCM’s). Therefore the integration of RCM’s into local decisions, and the integration of RCM’s with local models, is a crucial factor.

5. Overview of the SUDPLAN project

SUDPLAN is a research project which has addressed a call for proposal issued by the European Commission within the 7th Framework Research Program (FP7), in particular in the activity named ICT for Environmental Services and Climate Change Adaptation of the Information and Communication Technologies (ICT) program [14]. One objective of this call was R&D towards decision support for urban planning, taking into account climate change predicted by RCM’s. The call was specifically asking for solutions which combine 3D/4D modeling, simulation and visualization with the above mentioned service-oriented SDI’s.

The main idea of the SUDPLAN project is to develop an easy-to-use web-based planning, prediction, decision support and training tool, for the use in an urban context, based on a what-if scenario execution environment, which will help to assure population’s health, comfort, safety and life quality as well as sustainability of investments in utilities and infrastructures within a changing climate.

SUDPLAN aims at a new and visionary capacity to link existing environmental simulation models, information and sensor infrastructures, SDI’s and climatic scenario databases, providing visualization of long term forecasts of environmental factors for urban subsystems such as building and architecture, traffic and transport, landscape planning and local water runoff.
End-users shall be enabled to evaluate risk hazards of e.g. river flooding, storm water local runoff, elevated air pollution levels for planned or existing urban areas subject to a changing climate.

5.1. End user needs

The SUDPLAN system will serve three types of users:

- **Expert planners**
  (scientific users, for instance modelers)
- **City planners**
  (less scientific users, for instance city planners, administrative users, ...)
- **Developers / application providers**
  (support the first two groups)

All three groups are important for the applicability of advanced urban planning. The first one – a more scientifically oriented group of users – will develop different alternatives decisions either for themselves (in their own daily work) or for less computer-skilled planners in city councils. For this group of users, the system shall be very powerful and flexible. They may generate customized applications for the second group. The second group is important as they are the ones who support the decision taking in city councils. In many cases they may require a more simplified planning model, but some of the users in cities may also fall under the first category of scientific users. Both end user groups may and will be assisted by system developers and application providers where necessary, in particular when it comes to customizing and extending the core SUDPLAN product.

The main obstacle which the first two user groups face today is that there are too many autonomous applications for flooding, water runoff, or air pollution. Some also include risk assessments with a changing climate. Often, each tool uses its own data store, often models are hard-wired into the application front end, analysis is often done in “yet another” product, often many products are closed and adaptations are difficult to undertake, which is part of the reason why EDSS are often too expensive.

While the first user group, scientists, are used to a multitude of tools, the second user group, practical planners, cannot afford to work in such an environment, including for financial reasons.

The project intends to close this gap by providing planners and decision makers in the urban context with a “web-based scenario management environment”, which is easy to adapt to a local situation and which makes a wide range of EDSS for climate change practically affordable.

This tool will allow them to manage scenarios, to execute, visualize and compare them with each other and with real developments over 3-dimensional space and time, in order to carry out scenario-based prediction, damage assessment, planning and training, which uses 3D/4D modeling, simulation and visualization coupled with existing resources like sensor networks. With SUDPLAN implemented, the end-users will have available integrated and higher quality information regarding urban environmental factors of today and for future scenarios, as the SUDPLAN system will allow on-the-fly combination and production of forecasts from different types of models, sensors and geospatial information in 2D and 3D space.

5.2. Project goals

First of all, SUDPLAN is designing and implementing a scenario management, execution, visualization, documentation and training environment for scientific users and city managers, which conforms to the following key requirements: a.) to allow for better preparedness, decision support and mitigation of climate change impact on population, utilities and infrastructures; b.) to use what-if scenarios to model impact of decisions; c.) to include highly interactive, 3D/4D visualization beyond the state-of-the-art; d.) to seamlessly integrate with existing models, from the European down to the local scale; e.) to seamlessly integrate with existing and emerging distributed infrastructures for spatial data, services and sensors, which includes the requirement to be standard based wherever possible.; f.) to be highly usable, adaptable and flexible, which includes the requirement that business processes are not hard-wired in the system.

Secondly, by applying the system, the goal of the project is to improve information and service quality in the area of risks for flooding, heavy rainfall and severe air pollution episodes, affecting urban infrastructure and population, and under the influence of a changed climate. This will be accomplished by applying modeling techniques covering the full service chain of models and data required, thus providing urban planners on all levels of the decision chain with vital information to assure sustainable city growth for the future.

Thirdly, SUDPLAN is implementing services based on RCM’s (the so-called Common Services) which allow to quantify, report and visualize the future risks for flooding, extreme rain intensities and high air pollution events over urban areas. These services shall be usable throughout Europe, and shall serve as input to local decisions.

These goals shall be achieved in such a way, that the SUDPLAN services and tools can easily collaborate with existing, established infrastructures, and that the SUDPLAN services achieve a maximum of flexibility and adaptability to national or regional
differences, which shall make the application of SUDPLAN efficient and cost-effective.

6. System concept

The core product is a highly interactive, highly 3D/4D graphics-based decision support environment in the form of a scenario management system, which explores existing resources, in particular the 3D landscape and 3D models of phenomena. In this system, users are capable to define, manage, execute and explore different decisions and to simulate decision scenarios. Users are supported in the visualization, comparison and documentation of different decisions, and can use the system for training.

The product will contain the following major components (fig. 1):

a) a tentatively called “orchestrator” component, which allows to define different what-if decision scenarios, their data and sensor sources, the models involved and the workflow associated with the scenario

b) a tentatively called “executor” component, which allows to execute (i.e. compute) different decisions (while the user waits, or in the background), to compare and document results

c) a geo visualization component which links with existing SDI infrastructures (i.e. the existing spatial city information)

d) an advanced 3D / 4D visualization component for the visualization and animation of 3D results and predictions, in particular using the 3D landscape

e) a scenario and persistence manager which keeps an inventory of scenarios, data sources and results which supports results evaluation and reporting

f) an access-controlled layer to existing services (including models), data sources, catalogues and sensors.

The functionality of the system includes (not including tools for system managers):

- discovery of available resources (data, models, published scenarios etc.)
- integration support for data sources, sensors and models
- support to set boundary conditions of models
- scenario workflow management
- scenario management

Fig. 1. System concept
• repository support, for instance
  • result storage
  • result documentation and annotation
  • export functionality
• post processing of results
  • comparison of results, differences between them
  • impact assessments, cost, damages
  • filtering of results according to goals (what the user wants to see)
• advanced visualization capabilities
  • 2D / 3D and 4D (animation) of results, differences between them
  • both using the physical world as visualization paradigm (visualization over the landscape) and artifacts from advanced information visualization
• some support for data exploration

These functionalities will be available in a highly interactive adaptive “work bench”.

The following subsections explain how the general vision of the system as outlined in fig. 1 is translated into the technical development. It also explains which technical solutions are anticipated. The following chapters proceed from bottom upwards, from the service infrastructure to the end user application.

6.1. Communication and service infrastructure

SUDPLAN will connect to existing systems and infrastructures using existing service-oriented architectures. The SUDPLAN communication and service infrastructure (see (1) in fig. 1) will be based on the standards and specifications of OGC, in particular [15, 16, 17, 18], and will re-use results of projects ORCHESTRA [19] and SANY [20], in particular concepts, specifications and software components, as well as other open source software, where appropriate for the communication and service infrastructure.

Two major areas from these projects are suitable for re-use: first ORCHESTRA and SANY offer a sophisticated, systematic and well researched methodology for the design of service networks (with ORCHESTRA focusing on the general systematic approach as required by INSPIRE, and SANY focusing on sensor services). SUDPLAN will use this methodology, which will lead to a very systematic approach of the SUDPLAN architectural design. Secondly, both projects, along with open source software in the field of geospatial applications offer software components which support the integration layer of SUDPLAN.

6.2. Connecting information and services

External information sources and services which are used by SUDPLAN workflows, are connected to the system (see (2) in fig. 1) through access and web processing services defined by OGC, ORCHESTRA and SANY, and implemented by ORCHESTRA, SANY as well as other open source projects. SUDPLAN is making pragmatic choices of what the respective projects offer. In any case the baseline for communication will be open source products.

6.3. Security and service access control

Security and service access control in SOA is ongoing research and development. The specifications of OGC do not cover this issue and many of the existing products are proprietary. As part of ORCHESTRA and SANY research results, a generalized access control architecture supported by dedicated set of services and tools is available to SUDPLAN, including the software implementations.

For the access control layer of the system (see (3) in fig. 1) SUDPLAN will use the research results and software of the SANY project which are available as open source implementations. Between a client and a service is an access control layer, which verifies the identities of clients, manages policies and enforces such policies when service calls are made. The baseline for the implementation is the CHARON framework [21,22].

6.4. Persistence management and repository

Users will define “what-if games” in the SUDPLAN graphical user interface (GUI) which support alternatives in their decision support. These scenarios, their execution environment, their results and analysis need to be stored in a persistent way. For this purpose a scenario repository (or inventory) for long term storage and a persistence manager will be implemented (see (4) in fig. 1). For this, standard open source database technology will be used, for instance Postgres, as it supports the storage of geographical features as well.

A major part of this research will be the development of a model (or a meta-model) which can capture the term “what-if scenario” in a way that it can be implemented in a database schema. In this research it will be essential that the scientific end users and the computer scientists closely collaborate on concepts and terminologies, because this will be the backbone of the entire system.

6.5. Scenario manager, orchestrator, executor

In terms of EDSS research results the scenario manager (see (5) in fig. 1) will be the main contribution to the state-of-the-art. To our knowledge such a component has not been built on top of a SOA-based approach as part of an EDSS environment. It is
the central point in the GUI in which users define scenarios, workflows, schedule them for execution, schedule result analysis or go to other parts of the system (like the interactive visualization components).

The goal for the scenario manager is that it will become a tool for scenarios which behaves in a way similar to Integrated Development Environments (IDEs) for software (for instance Netbeans or Eclipse). This will be an environment which lets experts define projects, define interfaces to external resources, workflows, and dependencies. Modern software development concepts including automated deployment will facilitate the whole scenario development cycle, similar to modern IDEs.

The different types of users mentioned earlier (scientific, less scientific, developer) will see the system in different expert modes. Where more expert users may see workflows or adapters to external resources, end users in administrations may only see a heavily customized GUI.

One component related to the scenario manager is the tentatively called “orchestrator” component (see (5) in fig. 1). This component will allow the definition of work flows, which the scenario manager can parameterize for different executions of alternatives (for instance of different RCM input data).

As mentioned above, this component will use prominent open technologies where possible, however major parts will have to be implemented from scratch.

The scenario executor will execute scenarios chosen and will allow parameterisation of work flows with different data sets, models or boundary conditions, i.e. it will be possible to execute workflows (see example in fig. 2) multiple times with multiple parameters.

6.7. GUI, visualization, analysis and reporting

Both traditional geographic visualization and 3D/4D visualization play a key role in the SUDPLAN product (see (7) in fig. 1). The GUI will include both 2D and 3D visualization and interaction paradigms. The 3D / 4D visualization component of the system provides a framework incorporating/combining a number of visualization algorithms for interactively visualizing different scenario aspects:
• geometric visualization algorithms, for the display of terrain and city models as well as geometric simulation results, for example water levels
• volume visualization algorithms, for visualizing volumetric data and simulation results, for example distribution of air pollutants
• information visualization algorithms, for visualizing important features of the data like hot spots or areas of high impact and the in situ presentation of underlying information like statistical or simulated values, as well as for the comparison of different what-if scenarios.

This framework allows the users to combine the different kinds of algorithms, depending on the underlying data (geometric, volumetric or information), into one interactive visualization for analysis of the simulation results or presenting the intended statement to other user groups.

In addition to the visualization algorithms, the visualization component incorporates interaction techniques enabling the user to analyze data in an interactive way, including comparison of different simulated what-if scenarios and controlling the display of 4D data, e.g. the progression of flooding or water levels in the drainage system due to heavy rainfall.

Furthermore the visualization will provide different output profiles to take different types of (stereoscopic) displays into account to simplify the use of the visualization in different hardware setups. This allows on one hand to use the visualization in a single-user environment (2D or 3D display) for modeling, comparing and analyzing of scenarios and on the other hand to present or analyze the results in a multi-user environment on large (tiled) displays or immersive multi-user systems.

Particular emphasis will be put on “deep” integration between advanced 3D / 4D methods and traditional geo visualization.

7. System validation

The system will be validated in four different and very diverse pilot applications in Stockholm (Sweden), Wuppertal (Germany), Linz (Austria) and Prague (Czech Republic) in order to ensure that the approach is generic, easy to use for service providers and end-users and is easily transferable to other sites.

All pilot applications are based on real world needs and will support planners in solving problems related to potential climate change issues. In all pilots, it is planned to us so-called “Common services”, a set of services which enable local pilots to use different RCM scenarios as input parameters.

7.1. Pilot 1: Stockholm

The 26 municipalities of Stockholm County host around 21% of Sweden’s population within 2% of its land area. In 2006 the regional actors (the 26 municipalities, the rail track and road authorities, and the chamber of commerce among others) jointly engaged in a process aiming at producing a new regional development plan, due to be ready for political approval in 2010. The process is led and facilitated by the Office of Regional Planning and Urban Transportation (RTK). The plan will cover both spatial/physical and social and economic issues and thus have a truly integrative scope. Climate change impact assessment and adaptation studies will constitute some key elements of the planning process.

An example where climate change is believed to give a changed and stronger impact in Stockholm is storm water flooding. Air pollution is already today a critical issue in Stockholm and the European Commission has had to start infringement proceedings against Sweden for failing to comply with the EU’s air quality standard for dangerous airborne particles known as PM10.

The Stockholm pilot will include SUDPLAN services which will provide local authorities and institutions in the region with trends in downscaled rainfall, air quality and ambient temperature. The Stockholm pilot will focus on the demonstration of a sophisticated urban planning tool for avoiding hazardous air pollution events today and in the future. The simulation of the environmental factor air pollution will seamlessly downscale to the micro-scale of individual city blocks or streets, allowing the user to assess the origin of air quality on all scales and to combine climate scenarios with local changes in urban infrastructure and systems.

The largest health effects come from exposure to ozone and small suspended particles (PM10). Both of those pollutants are, to a major part, originating outside Sweden and transported with the wind from the European continent. Changing temperature, precipitation and vegetation in Europe will alter the processes behind the formation of ozone and inhalable particulate matter. It is important for the Stockholm administration to regulate local emissions so that a clean and safe air quality can be maintained for present conditions as well as during and after a gradual climate change.

7.2. Pilot 2: Wuppertal

The city of Wuppertal is located in the steep, narrow, long valley of the Wupper river. The location is so narrow that more than a hundred years ago, the city went in the 3rd dimension for public transport, and built the famous Wuppertal Suspension Line.
Due to the geographical situation of the city, the main concern regarding climate change impact is uncontrollable, extremely localized run-off from increased heavy, short rainfall events. For instance, an event in 2007 caused heavy local damage and first went completely unnoticed in the city hall, located only 2 kilometers away, where the sun was shining.

The potential damage of public infrastructure and of private property is a major concern to the city managers. The potential needs for investments are huge, considering that the city copes with run-off from 350 kilometers of creeks (over 800 creek sections) and 650 kilometers of drainage channel system. Due to the complex geography, it is completely unpredictable where a heavy rainfall event might occur, and when it occurs it is today unknown whether there will be flood and where it will run off. Due to the huge investments required, it is also not possible to just increase the profile of all, or even only of major parts, of the drainage system. The Wuppertal pilot will therefore concentrate on heavy, short rainfall events and their impact on the infrastructure.

The city administration has put a project underway to develop a master plan, during the coming 5 years, which shall identify the most vulnerable areas and shall suggest different localized planning options which are likely to prevent damage and are yet practical to be implemented, including being capable to cope with financial constraints.

The planned approach is to invest in a high-resolution, 3-dimensional information space covering the whole of the cityscape, and to use high-resolution 3D/4D modeling to assess different planning options. Advanced 3D/4D visualization is considered key to the success of delivering results of such model.

7.3. Pilot 3: Linz

Urban drainage systems form a valuable backbone of urban infrastructure. On average, it is estimated that the value of the urban wastewater system is about 300 Mio € per 100,000 inhabitants. In most European cities waste water and storm water are drained in one sewerage system (“combined systems”). Thus the urban wastewater system is very vulnerable to potential climate change impacts, particularly to a potential increase of extreme flood events. One of the critical issues in storm water management is within a waste water treatment plant (WWTP). Due to the hydraulic limitation of WWTPs it is not possible to treat the whole amount of drained water at WWTPs; thus the runoff in combined sewer systems has to be either discharged at combined sewer overflows (CSO) into receiving waters or stored in reservoirs.

Climate change impacts considered a threat to urban infrastructure are potential increase of heavy rainfall and accompanying sewerage flooding. The urban infrastructure has been built according to historic standards of frequencies and extents of flood events. With climate change these historic standards need to be re-written. It will not be financially feasible to re-build the sewerage systems to cater for future climate variability. What is possible, however, is to counteract the potential climate impacts with a better and smarter operation of the sewerage system, using advanced ICT solutions. Monitoring of the waste water system and scenario simulation of potential climate change impacts are essential for the optimization of sewage flow control in order to ensure the smooth operation of existing infrastructure, to prevent environmental damages and to extend the operational lifetime of the urban infrastructure.

The Linz case study will explore the suitability and applicability of an innovative communication and information system for the improved operation of the sewerage system under possible climate change conditions. Special emphasis will be given to using information from different sensor types to ensure an early response to flood events and to an appropriate management. Such innovative systems can be applied to the combination and integration of information from sensors of any kind (e.g. rainfall in sewerage catchments, wastewater qualities, extent of free primary and secondary sewer capacities in different networks, extent of suitable zones for planned emergency spillovers ...).

7.4. Pilot 4: Prague

This pilot is looking at the greater Prague area, and put the city into sub-urban and regional context, and will consider how the city interacts with its surroundings and vice versa. The Central Bohemia region covers an area of 150x150km around the City of Prague and is a Prague catchment area. In terms of business, education, health care etc. Prague has lost 5% of its inhabitants during the last 15 years as they have moved out to the Central Bohemia region, creating a huge pressure on the environment. Any change in quality of life in the region may have impact on the population movement again. Urban sprawl and population movement to suburbs are the two major threats in Central Bohemia.

Central Bohemia is also known for its agricultural production. While only 3% of the population in the region work in agriculture, they manage 40% of the land area. Drying of the land, major run offs or any other adverse impacts on the soil may have major influence on the behavior of farmers to give up agriculture and take the job in industry. Such development will have many adverse effects on the structure and functions of the landscape.
Air quality is expected to change a lot with climate change induced temperature variations. Quality of life in the Czech Republic today is heavily influenced by the ozone and PM10 situations. The number of private cars and trucks has doubled since 1990. Higher utilization and growth in commuting heavily affect air quality thus have a substantial impact on health and quality of life of Czech citizens.

Prague, like other major cities in moderate temperature zones, faces population migration towards suburbs, because of ever increasing temperature, smog, decreasing air humidity and so forth. Especially young families consider moving from the city to suburbs or satellite settlements, which has a major impact on traffic with causal connection on air quality.

Climate change brings more weather and precipitation extremes, stronger winds adversely affecting ecosystems including arable land. For instance, temperature increase, changes in precipitation and air pollution levels, both expressed as yearly totals and as extreme values, as well as storm frequencies expected to occur during the coming decades [12,13] will invalidate those historical time series analysis and call for new statistical assessments based on forecasted weather scenarios up to and beyond 2050.

Lower yield puts stress on farmers whether to continue cultivating the land or to abandon it. More and more farmers are giving up and start taking different jobs. Unused land is then turned into residential, industrial or commercial zones in particular when there is a good transportation network.

Because of all these effects, this pilot will therefore particularly look at: a) the movement of inhabitants as a function of changes in precipitation, soil humidity, air quality etc., and b) changes in the landscape as a function of changes in precipitation, soil humidity, air quality etc.

7.5. Common system pattern

In the traditional approach, each of these four EDSS would be built in an individual integration project for each individual case. They would be tremendously expensive.

With the ambitious goal to build a generically useful tool, SUDPLAN aims at considerably reducing the efforts to build a custom EDSS, and to provide patterns for classes of EDSS. In case of the SUDPLAN case studies, the pattern will look like in fig. 3.

8. Discussion

There are several ways how EDSS have been built in the past and how users interact with them. The traditional approach of “hard-wiring” models, visualization, data access and so forth (for instance in [23]) is an expensive one, as argued in section 1. With the upcoming SOA approach this hard-wiring has been replaced by loosely-coupled services, which allows for easier re-use, but the work flows are often fixed (for

![Fig. 3. Typical application pattern](image-url)
instance in [24]), either in a client, a service or a fixed service chain executor. In both cases, traditional and SOA-based, the application is a fixed one. There have been successful experiments with on-demand composition of service chains, for instance using semantics to choose from different services at run-time [25], and the choice is often done by the end user. On top of that the need has been identified in [26] to link modeling environments with SOA-based infrastructures in order to minimize the effort to build an EDSS, but no work towards this goal has become obvious. In this complex environment of system design, the major contribution to the state-of-the-art expected from SUDPLAN is directed towards the end user, an often neglected entity. By automating recurring tasks, by properly managing modeling experiments, data and results, decision makers shall be enabled to perform their tasks more efficiently and with better quality.

9. Project status
The project is following an iterative development approach with several development cycles. Over the period of three years, several versions of increasing functionality will be built and validated with the pilot applications. At the time of this submission (June 2010), the first versions of end user needs assessments and requirements specifications are being finalized and prototypes are being increasingly implemented. At HICSS-2011 the first versions of software and pilots will be operational and a detailed consolidated requirements base will be available.

10. Acknowledgements
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