

Research Proposal, DINALOG, May 2013

IT Services for Sychromodality (SychromdallIT)

Full Proposal Project Plan

Summary

Motivation and goals

Three major challenges have motivated this proposal: the need for a unified European logistic network, the need to increase the efficiency and sustainability of logistic services, and the ambition to trigger and push the “mental switch” of both shippers and 4PLs , towards a sychromodal way of working, in which the decision about the mode of transport for the next part of a route is made as late as possible, allowing optimal flexibility in routing and improved quality of service and sustainability. Therefore, the main objective of this project is to enable efficient, reliable, and sustainable delivery of logistic services and strengthen the Dutch logistic sector through

- the design of an sychromodal logistic network model and integrated service platform,
- the development of related planning and scheduling policies, and of decision support through serious gaming.

Activities/Work packages

We defined three knowledge-creation activities (each representing a separate PhD project): A1 – Real-time & Big Data, A2 -Planning & Gaming , and A3 - Architecture & Services. Additionally, we have defined three supporting activities, which are meant to facilitate and enhance knowledge creation: A4 Valorization has been defined to motivate the use of the results of our research in practice, A5 describes the dissemination of knowledge, and A6 concerns the management of the project. The knowledge-creation activities A1, A2, and A3 are closely related to each other, as A3 can also be regarded as a testbed and validation support for A1 and A2, which in turn provide input for A3.

Expected results/ Innovativeness

The “selling point” and innovative strength of this proposal reside in the **unique combination of operations research techniques, information technology, and serious gaming to enable sychromodal planning**. Based on the results developed in this project a significant amount of added value in innovative sychromodal logistics for the Netherlands will be generated. The expected results are very diverse. We expect a large number of scientific papers and three PhD theses. Next to this, many Master students do their internship in the companies in our consortium, leading to a large repository of information for our project. A number of decision making scenarios will be developed, leading to innovative pilots and implementation of new logistic services. The outcomes are expected to have long- term effects for all participants on their actual decision-making in freight transportation.

Valorization/implementation

Valorization and knowledge dissemination are key aspects of our project. We have a consortium of industry-leading companies that help to develop best-in-class concepts and tools. We actively support the application of concepts and tools among logistic consortium partners and the development of new ventures based on management games and software services developed in

SynchromodalIT. Consortium partners will be encouraged to develop and market commercial solutions based on the results of this project. We will apply knowledge developed in this project through amongst others MSc student thesis projects in logistic companies and development of training/teaching materials. Knowledge dissemination will be done through a variety of media: professional magazines, academic journals, and conferences (both academic conferences and dedicated workshops and seminars for practitioners).

A. Orientation and Project Goals

Motivation

Throughout history, The Netherlands have been an important logistic and commercial hub due to its geographical location. This function is still essential for its competitive position in the European and international economy. It is therefore of strategic importance for The Netherlands to offer excellent transport infrastructure and logistic services for all transportation modes. However, due to continuous growth of freight volumes and to heavy congestion of roads, it becomes critical to find ways to make logistics more efficient, and to change significantly the current modal split [2,4]. This is in line with the most recent European and national policy documents [1,2,3]. Among the key goals set for the coming 20 years are: “an efficient core network for multimodal intercity transport”, “optimizing the performance of multimodal logistic chains, by making greater use of more energy-efficient modes”, “60% GHG emission reduction” (by 2050), and “Increasing the efficiency of transport and of infrastructure use with information systems” [1].

In recent years, the logistics industry remarkably changed in that the planning and monitoring of logistics functions is no longer a task performed by customers of logistics service providers (LSPs) (e.g. vendors, manufacturers), and often not even by LSPs, but by a number of so called value-added logistics or fourth party logistics service providers (4PLs, term coined by Accenture) respectively. 4PLs essentially is an aggregator of, “resources, capabilities, and technology of its own organization and other organizations to design build and run comprehensive supply chain solutions.” It provides basic logistic services such as transportation, handling, storage of goods, packaging, clearing of goods, etc., but also process coordination and planning. Within a network of affiliated LSPs, for each order a 4PL selects matching LSPs according to the needed services and integrates them in order to meet customer’s requirements. Moreover, a 4PL governs and optimizes the overall process, and acts as a prime contractor for the customer. 4PLs are the main contact party, take care of the coordination of all LSPs involved, and have the responsibility for the overall process and its quality of service.

Throughout the last decade, in European logistics there has been a growing interest among 4PLs in intermodal transportation. Intermodal transportation involves transport of freight using multiple modes of transport. Due to recent developments in the ICT, the number of opportunities of transporting freight using multiple modalities has increased. A recent development is the study on synchromodal transportation. Here we face an intermodal transportation network where the choice of modality is not fixed up front, but is made for each order individually and might even change during the course of transportation. Thus, the synchromodality concept is synonymous with the creation of an optimal, flexible, efficient, and sustainable transportation in which 4PLs can choose not just among logistic providers but also from a range of modalities at any given moment (through easily switching between modalities if necessary), and for any given order.

As mentioned before, one of the main activities of a 4PL is to perform the planning process for its

customers. This activity becomes even more critical in the context of synchronomodality. Depending on specific requirements, the synchronomodal planning process includes (i) selecting the best combination of modalities and corresponding carriers for each order, (ii) defining the service chain and detail planning of each order, (iii) monitoring the logistic processes, (iv) managing the contracts with preferred carriers, (v) consolidate LTL shipments or even FTL shipments for barge and rail transport, (vi) managing the division of costs and gains for players involved, and (vii) building long-term forecasts in order to assure a viable and robust logistics process. The new way of working requires contracts with logistics service providers (LSPs) that contain agreements on price, delivery time and quality, but the modalities can be chosen by the LSP itself. The LSP has the freedom to use all modalities resulting in cheaper and more sustainable transport. This requires more ICT than in non-synchronomodal situations for advanced information systems and software capable of planning using this information.

The current practice is that for each of the above-mentioned tasks different, heterogenous, non-integrated and not interoperable data sources and software systems are used. Although these systems generally support and cover most steps of the planning process, the results of these steps are still isolated (as they they are stored in different systems), inefficient and error prone (much data is replicated in different systems and, therefore, might be inconsistent). Furthermore, integration with business partners (i.e., customers and partner LSPs) is handled via EDI messages, e-mail, fax, or even phone. Therefore, coordination between parties in such multi-actor business network, and of the process and planning steps by means of one integrated system architecture is essential in order to avoid errors and to increase the efficiency and quality of the synchronomodal planning, and for guaranteing the required service levels. To achieve this integration, next to the need for smart dynamic optimal synchronomodal planning techniques, several problems (described below) related to data and system interoperability [25] and integration must be addressed.

Challenges

A number of on-going economic, societal and environmental developments (such as, intensification of freight moves and growth of freight volumes, increased congestion of roads, efforts to reduce greenhouse gases emissions, technological changes in the logistic infrastructures, etc.) give rise to a number of challenges (denoted hereafter with C1 – C4) that are described below.

In the last decades both the infrastructure and logistic services on road, rail, and water have grown significantly. Furthermore, all infrastructure networks have become technologically more advanced, as they are enriched with built-in sensors, automated monitoring systems, and various (traffic) information services.

The European policy documents [1] now talk about moving from logistic corridors and distinct modes to a unified European synchronomodal logistic network. This is a first major challenge, from the IT point of view. Each of the above-mentioned infrastructure networks has specific physical and informational properties, and different logistic facilities, capacity and traffic control systems.

Currently there is no unique information model of this unified network. Although for each modality, infrastructure network models and navigation systems that run on top of these models do exist, it is not clear how these should be integrated, where in this network modal switches may occur, how the state of such unified network can be captured and managed in nearly real-time [32, 33], and what the semantic and pragmatic interoperability issues [8, 25] posed by such integration are (**C1**).

Finding answers to these questions is a prerequisite for a true Synchronomodal Logistic Service Provisioning (SLSP).

The second challenge for SLSP is to provide decision support for dynamic planning of logistic services for the human planners (**C2**). This requires the development of algorithms for route and modal mix selection, that produce efficient solutions with respect to costs, sustainability, and service quality (e.g., timeliness of transport). These algorithms should be able to (i) provide the human planner enough freedom to cope with the customer requirements, (ii) create efficient route and modal mix selection based on multiple criteria (e.g., cost, sustainability and service quality), and (iii) accommodate modifications resulted from infrastructure state changes (e.g., calamities) or of unforeseen events (e.g., traffic disruptions).

As pointed out in [1], SLSP is not possible without information technology for the automated coordination of SLSP processes, which constitutes the third challenge (**C3**). Thus, there is need for a flexible IT integration platform, that will provide logistic information, monitoring, and coordination services, and facilitate interoperability in SLSP networks.

Finally, maybe the greatest challenge of all, concerns the human factors, namely the “mental switch” of both shippers and 4PLs, towards the synchromodal way of working, and its benefits (**C4**): no loss of service quality and more sustainability. Now, 4PLs are not always authorized to decide on their own upon a possible modal switch. For that they may need the shipper’s approval. Therefore, it is critical to make them experience and become convinced of the advantages of synchromodality. To achieve this, simulation and serious gaming built around optimal planning services can play an essential role.

Research themes

In order to address the above-mentioned challenges we identify three lines of research (and their corresponding research questions). Each of this lines of research will constitute a PhD project focusing on the specific research questions formulated for that line of research.

Research line 1 – Real-time & Big Data: Concerning logistic infrastructure data management, we focus on both static and dynamic aspects:

- a. What are information requirements of a 4PL to efficiently and effectively run synchromodal services?
- b. How to integrate the different infrastructure networks required for SLSP and their connection points into a data model?
- c. How to integrate online data to infer the current state of the infrastructure network [13]? What type of techniques should be developed (e.g., web&text mining, trend-detection, etc.) and used to extract relevant information from such big-data collections?
- d. How to predict the future status of the infrastructure network based on the similarity with the recent history and documented situations contained in a big data collection?

Research line 2 - Planning: Concerning optimal synchromodal planning techniques, we consider the following problems:

- a. How to generate high quality solutions, using operations research (OR) algorithms, for flexible on-demand planning of SLSP, such that, (i) modalities can be selected short before or even during transport, (ii) the human planner is provided with a number of routes to choose from, and (iii) a modal mix is selected such that costs and CO2 emissions are minimized [7], while the service level of SLPS is preserved?
- b. How to support the consolidation of shipments in a synchromodal transport setting (both consolidation of LTL shipments in one container as well as FTL shipments on barge and rail

- transport) and how to share the costs savings among the parties involved?
- c. How can information on historic job patterns be used to improve the planning of transport and consolidation of shipments?
 - d. How can real-time information (e.g., regarding traffic congestion, delayed deliveries, broken locks) be used to adjust the planning dynamically [9] of SLSP (e.g., route planning, or smart bundling) [11,12,14]?
 - e. How can serious gaming and simulation extend and complement the planning techniques by bringing “the human in the loop”, and lead to a “mental shift”[6] of 3PLs and shippers towards synchromodality?

Research line 3 – Architecture & Services: With respect to a platform for smart pluggable services for SLSP networks, we consider the following aspects:

- a. What are the enterprise architecture requirements of logistic companies with respect to an integration platform[7] that realizes (i) the integration with back-office systems, on-board devices, and other data sources, (ii) provides pluggable information services, and (iii) supports SLSP?
- b. What are requirements of different partners in the logistic chain for pluggable information fusion, business intelligence, and monitoring services, and for decision support services (e.g., real-time planning adjustments) [10, 32, 33]?
- c. How to handle system, process, and semantic interoperability problems in the logistic network (where such problems depend on the partners’ diversity and autonomy, and on the heterogeneity of employed technology/data sources)[8] with interoperability service utilities [25]?
- d. Which billing/payment/cost-gain sharing services can be offered to partners in the network, which dynamically adapt to changes in operation and market conditions?

From the formulation of the research questions, the following mapping of the challenges onto research lines becomes apparent:

C1	C2 & C4	C3
Research Line 1	Research Line 2	Research Line 3

Deliverables

We focus on developing the following deliverables:

Research line 1 - Real-time & Big Data:

- An logistic infrastructure data model and data services suitable for supporting advanced synchromodal planning and monitoring services
- Data mining tools for extracting static geo-spatial information from historical data
- Real-time data processing techniques to extract information, consolidate the information and explicate a quality or confidence level
- Develop techniques that use historical data to make short/long term predictions about the state of the logistic infrastructure

Research line 2 – Planning & Gaming:

- Advanced synchromodal planning algorithms to support offline as well as online and (nearly)

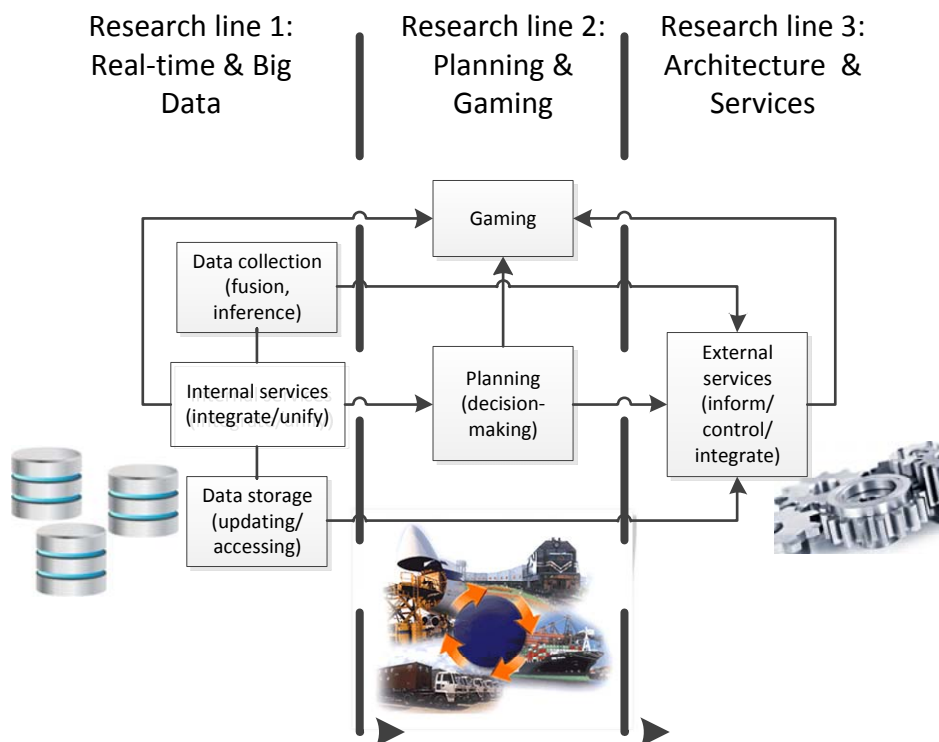
real-time decision making.

- Quantitative model that characterizes the relations between shipping patterns, logistics costs, logistic service levels, greenhouse gas emissions, and commercial benefits of LSPs.
- Dynamic pricing mechanisms for LSPs in order to optimise their revenues within strategic constraints.
- Business rules for consolidation of shipments and cost and gain sharing.
- Forecasting methods for transportation requests and shipment prices, to be used for decisions regarding consolidation (should transport be postponed in anticipation of a consolidation order) and negotiations with shippers.
- Discrete event simulation models to evaluate and improve all the above planning algorithms, pricing mechanisms, business rules, and forecasting methods.
- Serious games that use all the above planning algorithms and pricing mechanisms, business rules, and forecasting methods, in realistic decision making scenario's in which human planners in interaction with the system can choose from synchromodal planning alternatives and see the immediate effects of their choices.

Research line 3 – Architecture & Services:

- A 4C type of IT integration architecture for cross-chain information sharing between relevant logistic business network partners.
- A service platform for decision and planning support services for, e.g., synchromodal (nearly) real-time planning, dynamic pricing, performance/service levels monitoring, logistic infrastructure information services, etc.

The relationship between these three research lines is explained in the figure below:



Relation to Dinalog's innovation themes

The SynchronodalIT project is linked primarily to the **Synchronodal Transport theme**. New planning algorithms, architectures and information services are necessary for efficient and sustainable SLSP. These form the core of this proposal. Furthermore, a clear relation exists with:

- the specific **focal area 5**, concerning the human role in executing logistical innovations and in the optimization of logistic chains, through our focus on serious gaming (see research line 2). This focus is particularly relevant in a multiple stakeholder setting, such as SLSP, where time sensitive decision-making processes with high levels of complexity and uncertainty are required and assume the interaction between systems and human planners. Serious gaming stimulates analytic and strategic thinking .
- the **theme Cross Chain Control Center**, embodied in this project by the new integration platform, which may serve as real-time process coordination, monitoring, and execution engine.

Objectives and goals

The main objective of this project is to enable efficient, reliable, and sustainable delivery of logistic services and strengthen the Dutch logistic sector through

- **the design of an synchronodal *logistic network model* and integrated *service platform*,**
- **the development of related *planning and scheduling policies*, and of decision support through *serious gaming*.**

More concretely, the project objectives are as follows:

1. To substantially contribute to the development of scientific knowledge at the interface of, operations research, serious gaming and IT in synchronodal logistics.
2. To enable data interoperability and to trigger and stimulate the shift from logistic corridors thinking towards a unified logistic network by understanding the information requirements with respect to synchronodal logistics, by investigating the existing data models for the different logistic infrastructure networks, and by integrating them in a unified multi-modal logistic infrastructure data model.
3. To enable effective synchronodal services by enriching the unified logistic infrastructure network with publicly available dynamic (real-time) information that reflects the current state of the logistic network.
4. To develop techniques able to predict the future state of the logistic network, that can be applied to big data collections.
5. To ensure a flexible on-demand planning of SLSP, such that, (i) modalities can be selected short before or even during transport, and (ii) a modal mix is selected such that costs and CO2 emissions are minimized, and the service level of SLPS is preserved
6. To trigger a "mental shift" of 4PLs and shippers towards synchronodality and bring "the human in the loop" by using serious gaming and simulation in combination with optimal planning techniques during decision making scenario's.
7. To design and implement a platform architecture to support SLSP, that (i) provides solutions for the integration with back-office systems, on-board devices, and other data sources, (ii) provides pluggable information services, business intelligence, monitoring services, and decision support services (e.g., real-time planning adjustments), and (iii) handles interoperability problems in the logistic network (where such problems depend on the partners' diversity and autonomy, and on

the heterogeneity of employed technology/data sources).

8. To contribute to the development of human capital by means of a pool of about 20 students (5 per year).
9. Dissemination of knowledge to non-participants in the sector as well as outside the sector through open conferences, professional publications, case studies, workshops at Dinalog and MSc projects. We aim at 15-18 scientific papers, of which at least 6 will be published in ISI-rated journals. Drafts of first academic papers are expected towards the end of the first project year. We will commence with writing professional journal articles already by end of 2013.

We believe that this project can contribute considerably to the ambition set forward in e.g. the Topteam goal to become a market leader in logistics control. This argument is based on the fact that our project is supported by a variety of both IT and logistics consortium partners. Furthermore, we expect our consortium to grow in the near future as various potential consortium partners have expressed interest to participate yet were not able to give final commitment.

Expected results

The “selling point” and innovative power of this proposal resides in the unique combination of Operations Research, Gaming and IT. Furthermore, as far as we know, no (academic and practice) research has been done on the integration and development of a unified synchromodal logistic infrastructure model. Another novel idea we are proposing is the usage of serious gaming in combination with an SLPS software platform to create awareness and give adoption of synchromodality an impulse. This project thus aims at addressing a new class of data interoperability, integration, and management problems, important for both academia and industry. Therefore, SynchromodalIT’s theoretical, practical, and economic impact is expected to be very high. Many results developed lend themselves to practical application with the companies in our consortium and beyond. Note that the important stakeholders from the industry are involved in this project, guaranteeing direct use of the results, expected to lead to an increase in the Dutch GNP. More precisely, we believe this project may have significant impact on

- *cost savings*: as result of a business case we developed for several scenarios (with different degrees of Synchromodality), we have estimated potential for cost savings varying from 10% to 15% in the synchromodal situation,
- *CO2 reduction*: if we consider the model split in Nederland in 2008 (road 58%, rail 7%, and water 35%) [4], we can infer that by moving just 1% of the freight volume from road to waterways and railways we can achieve a decrease of almost 1% in CO2 emissions, and
- *congestion reduction* on roads: “Congestion costs are projected to increase by about 50%, to nearly 200 billion € annually”, at European level [3]. Assuming we can reduce congestion with just 1%, that alone would save 1,33 billion € annually.

From the academic research point of view, we expect to produce high quality publications (at least 15 papers, of which at least 6 in ISI rated scientific journals) and three PhD theses (one/research line). Knowledge dissemination will be facilitated through yearly practitioner workshops during which research results will be demonstrated. Furthermore, we aim at presenting/publishing our work at top international conferences (at least three participations/year). Other expected results are (for a detailed overview see the activity descriptions):

1. A data model for a synchromodal logistic infrastructure network

2. Prototype planning software and service platform
3. Serious game to support decisions related to our WPs
4. Series of workshops and seminars
5. SychromodalIT's website
6. Awareness creation via proof of concepts, pilots and demonstrations
7. At least 15 Master student projects.

Relation to government policy

As a follow up of the EU2020 Strategy, the European Commission has adopted a roadmap towards a competitive and resource efficient transport system. This strategy sets as main target the creation of a Single European Transport Area with a fully integrated transport network linking the different modes and aiming at optimizing the performance of multimodal logistic chains, and cutting carbon emissions [1]. On the other hand, The Netherlands has the ambition to become European market leader in the coordination of international transport flows in 2020 (De Commissie van Laarhoven), and increase the share of coordination activities in the GDP from 3 billion (2010) to 10 billion (2020). This should be possible through the development and implementation of logistic innovations in chain coordination, sychromodal transport, and sustainability, as indicated by governmental advisory board Topteam Logistiek [2]. This project is fully aligned with these documents, as it focuses on innovations related to sychromodal dynamic planning, coordination and CO2 reductions.

Orientation

The core research team has extensive experience with industry driven research projects where cooperation with practice is central, either through a consulting background or a background in industry. Three research groups from University of Twente are participating in this proposal:

Industrial Engineering and Business Information Systems group: researchers from this group have extensive experience with previous public- private collaboration projects such as those within the program IDVV from Connekt and Transumo. Three researchers currently participate in other Dinalog projects: prof. J. van Hillegersberg is active in the projects 4C4MORE and CATeLOG, dr. M.E. Iacob in the project CATeLOG, and Dr. M.R.K. Mes in the projects CargoHitching, CATeLOG, and CONCOORD (Joint Programming Initiative Urban Europe, co-financed by Dinalog), and all of them have participated in the IDVV projects BATMAN and "Sychromodal Control Tower" (SCT). The 4C4More participation ensures that insights into the technical and organizational aspects of 4C's can be linked to this project. Research regarding sychromodal planning (that we have carried out recently in the IDVV implementation project SCT (in which few of the present consortium partners were also involved) has been inspiration for formulating the research themes of this proposal. Although SCT was a short-term (one year) implementation project (in which many simplifying and limiting assumptions had to be made), it gave us the opportunity to understand the limitations of the implemented solution and the difficulty of the problems that have not been tackled yet. Therefore the current proposal has benefited greatly from this early experience, as it has been written while being very much aware of the theoretical, technical and practical state-of-the-art in this area. SCT represents an advantage also from SychromodalIT's consortium building point of view, as the current consortium has grown around a small core of partners than had successfully collaborate in the past, which ensures the continuity of the research.

Data base group: researchers of the database group have experience in managing large structured,

semi-structured and unstructured data collections. Furthermore, there is experience in handling huge amounts of data mainly in the field of information retrieval. In this context the first Hadoop cluster in the Netherlands has been set up by the database group, which is used in several EU funded projects. Besides of managing data there is also experience in transforming data into information especially in the context of social media. In particular, researchers have participated in a sentiment analysis competition of twitter data (SemEval2013 Task2 <http://www.cs.york.ac.uk/semEval-2013/task2/>) and a team of the database group has recently won the competition about making sense of microposts (<http://oak.dcs.shef.ac.uk/msm2013/>). In cooperation with DERI we have worked on combining different available data sources using non-monotonic reasoning approaches using real-time data.

Information systems group: researchers from this group participated in various industry driven research projects, both at a national and European level. The specific expertise that is contributed to SynchronodalIT is in the areas of enterprise interoperability, service architectures and context awareness. These areas are important to tackle the problems and attain the innovation objectives of SynchronodalIT as mentioned above. Relevant to these areas, the group participated in public-private collaboration projects including AWARENESS (BSIK project about context-aware infrastructures and smart services), SPICE (FP6 project on service infrastructures for innovative communication and dynamic service composition), and VALUE-IT (NWO project on commercial service bundling and multi-supplier service composition). The group is also actively involved in the IFIP TC5 Working Group on Enterprise Interoperability, which addresses the requirements of enterprise-level interoperability for performing collaborative tasks in value chains and business networks. This includes the for SynchronodalIT relevant work on pragmatic, process and semantic interoperability.

B. Activities and Work Packages

R&D Project SynchromodalIT	
Activity 1: Real-time & Big Data	Sep-2013 – Dec-2016
Activity 2: Planning & Gaming	Sep-2013 – Dec-2016
Activity 3: Architecture & Services	Sep-2013 – Dec-2016
Activity 4: Valorization	Sep-2014 – Dec-2016
Activity 5: Knowledge dissemination	Sep-2013 – Dec-2016

Activity 1: Real-time & Big Data

Description:

Synchromodality from a data point of view is a data integration problem. In particular, data describing a specific infrastructure network are required, represented as a directed graph consisting of nodes and directed edges. Different costs are associated to edges like e.g. CO₂ emissions, toll information, and expected travel times. Other data describe the capabilities of a hub, which is a location where cargo can be moved from one modality to another, which corresponds to a node in the infrastructure network of the modalities respectively. This data may contain information about expected time to perform the modality switch, the associated costs, and the hub's general capacity. The data so far focused a lot on infrastructure aspects, thus static information. However, situation dependent on real-time information has been mentioned already, like e.g. the expected travel time. This information is dependent on the current load of a hub or an infrastructure edge and therefore requires real-time information. Many of this real-time information is either freely available (e.g., <http://www.vaarweginformatie.nl/fdd/main/berichtgeving/scheepvaart/actueel>, etc.), or can be provided by project partners. The challenge of freely available information – also known as volunteered geographical information – is data quality. In particular, available information about the current state of an infrastructure edge might be faulty or contradicting. The reasons for faulty information can be wrong associated geo-spatial data, wrong content, or wrong interpretation of the data and therefore wrong information. To provide good information for the planning in Activity 2 it is important to consolidate the acquired data and potentially associate an automatically derived confidence level to the information.

The data so far addresses static and real-time data. To perform a planning task a prediction on the expected state of the infrastructure network as well as the hubs will be beneficial. This expected real-time information can influence decisions on the used modalities, the planning of the load of a fleet, or the path through infrastructure network.

Approach:

Concerning the data integration problem we consider the following four questions:

- **RQ1.1:** What are information requirements of a 4PL to efficiently and effectively run synchromodal services with regard to the logistic infrastructure networks and the dynamic information concerning them?
- **RQ1.2:** How to integrate into a data model the different logistic infrastructure networks required for SLSP and their connection points?
- **RQ1.3:** How to integrate real-time data to infer the current state of the infrastructure network

[13]? What type of techniques should be developed (e.g., web & text mining, trend-detection, etc.) and used to extract relevant information from such big-data collections?

- **RQ1.4:** How to predict the future status of the infrastructure network based on the similarity with the recent history and documented situations contained in a big data collection?

The **first question** (RQ1.1) addresses the information need of the user of the proposed system, thus corresponds to a requirement analysis step of a development process. The research will be conducted by a set of structured interviews. The result of these interviews is a prioritized list of required information and an assessment on the availability of this information. The requirements are then used to address the remaining research questions.

The **second question** (RQ1.2) will be answered by designing a data model for combining the infrastructure network. The expectation is that there is quite detailed geo-spatial information available for infrastructure networks (e.g. road-map systems), while information related to hubs, thus modality changing points, will be limited. Thus, the challenge is to actually integrate the different infrastructure networks into the designed data model. Furthermore, to integrate the potentially limited information about hubs and to automatically mine missing hub information from available historic information.

The **third question** (RQ1.3) addresses the development of data management techniques to support the derivation of real-time information about edges in infrastructure networks from real-time data [15, 16]. The used real-time data can be provided by project partners or be volunteered geographical information [17, 18]. The latter will require an interpretation and analysis of the data like e.g. named-entity recognition, sentiment analysis, or natural language processing. Furthermore, real-time data likely will contain contradicting information from either the same or from different sources [15]. A possible approach to address this issue is using non-monotonic reasoning. Our research focuses on data management infrastructure aspects to support the use of the above mentioned techniques and to explicate data quality measures.

The **fourth question** (RQ1.4) addresses the prediction of information about the infrastructure network including the hubs. The underlying principle is that the infrastructure network will behave similar in similar situations. This principle goes along with the principle in the Google translate service, where a word in a particular context will always be translated in the same way. Therefore, the aim is to find situations in the big data collections comparable to the current situation and use the historic information about the infrastructure network status to estimate the future status of the infrastructure network [19]. The challenge is to manage the large amount of data and to provide sufficient 'situation' describing information, such as, weather, road construction events, or vacation time information to find good matches in historic data [16]. The expectation is that Big Data tools like Hadoop and underlying techniques like HBase must be applied to handle the large amount of data and to perform the search operation in a distributed fashion.

Planning:

2013-2014

- Start of activity by reviewing the relevant literature on data models for multi modal logistics, geo-spatial data, real-time data, big data, and data mining.
- Inventarisation in collaboration with consortium partners of the 4PL's requirements for a comprehensive logistics infrastructure data model that can support synchromodal planning of logistic services.

- Design of the data model of the different logistic infrastructure networks required for SLSP.
- Receive education on methodological and conceptual issues related to this research methodology.
- Deliver a report for Dinalog on relevant data requirements for synchromodal planning, which also includes a detailed description of the complete research approach for the remaining part of this activity (and PhD project).

2015

- Develop, experiment and validate techniques for data management to support the derivation of real-time information about edges in infrastructure networks

2016

- Develop techniques that use historical data to make short/long term predictions about the state of the logistic infrastructure.
- Complete PhD. thesis.

Work distribution:

Much of the work in this WP is done by the Ph.D. candidate and senior researchers. Primary supervision of the Ph.D. candidate is done by the promoters Prof. J. van Hillegersberg and the daily supervision by promotor-assistants Dr. A. Wombacher and Dr. M.E. Iacob. Dr. Wombacher also acts as WP leader. Consortium partners are involved in input on research direction, participation in real-life experiments and involvement in data gathering/analysis.

MSc projects are used to link the scientific content of the project to practice. Students will be active in several areas: the exploration of the field (via case studies in logistic and IT companies), the gathering and analysis of data (e.g. surveys, transaction data) and the actual implementation of results in companies (also through case studies via case studies in logistic and IT companies). Each year 1-2 students will write their Master thesis on a topic from this WP. Students will be selected by the research team from the existing MSc students in Industrial engineering, Business Information Technology and Informatics at University of Twente.

Expected results/deliverables/milestones:

- A data model for an integrated multimodal logistic infrastructure network.
- ETL tools for data integration of geo-spatial data.
- Data mining tools for extracting static geo-spatial information from historical data
- Real-time data processing to extract information, consolidate the information and explicate a quality or confidence level
- Determine a context of the current situation to facilitate a search in historic data to estimate future situations.
- Provide a means to make geo-spatial data accessible to other applications facilitating open standards like e.g. Web Feature Service (WFS) from the Open Geospatial Consortium.
- Ph.D. thesis.
- 4-6 MSc theses.
- 6 scientific papers.

Activity 2: Planning & Gaming

Description:

With intermodal transport, cargo is transported between origin to destination, using several modes of transport: truck, barge, and train. With synchronomodal transport, the modes of transport are chosen dynamically for each order based on actual order and network characteristics. Commonly, rail and barge transport is used to move cargo on long distances, and is transport by truck is used for the first and last mile connecting the rail and barge movements to the origin and destination.

When considering all possible routes between a given origin and destination, a network containing several hubs can be drawn. A hub is a location where cargo can be moved from one modality to another. The trajectory between two hubs is known as a leg, and a connected sequence of legs between the origin and destination is known as a route. The set of all possible routes forms a so-called synchronomodal transportation network from which the planner has to choose. The challenge is to provide the planner with appropriate support to make this decision.

In its simplest form, this problem is related to the k-shortest path problem in which we search for the k shortest path in a network, see, e.g., [20]. However, in general, synchronomodal transport is much more complex. First, we might face complex timing restrictions, e.g., (i) time-windows on pickup and delivery, (ii) pre-defined time-tables for barge and rail transport, and (iii) closing times of hubs.

Second, there are possibilities to consolidate shipments: LTL shipments of different shippers might be combined in a single container, but barge and rail transport also provides opportunities to combine FTL shipments. Obviously, consolidating shipments from different shippers might result in additional challenges. For example, the consolidation of two shipments with conflicting time-windows might result in negotiation with the shippers on service level agreements and financial compensation. Third, we need to be able to support multi-criteria decision making, with the objective of minimizing costs and CO2 emission while maintaining delivery reliability. Various methods exist to find the optimal solution for a single objective problem, see, e.g., [20, 21]. Also, some progress has been made on multi-objective shortest path problems, where the output often consists of a set of Pareto optimal routes. Examples can be found in [22, 23, 24]. These methods could be used to support the tactical planning decisions involved in intermodal transport, where the decision regarding the combination of modalities to use is a long term decision made for various corridors (combinations of pickup and deliver region) in advance. However, these methods are not (directly) applicable to synchronomodal transport, where decisions have to be made fast in a non-stable environment based on real-time information. In addition, we face the additional challenges as mentioned before (time restrictions and the possibility to consolidate shipments).

To cope with the changing environment, unique customer requests, and real-time information updates (e.g., regarding congestion) human interaction is required to obtain a robust solution. To facilitate this interaction, decision support should be given to the decision maker, consisting of multiple route options from which he can choose. These options are generated based on multiple criteria (e.g., costs, duration, distance, reliability, lateness, CO2 emission) while taking into account possibilities for consolidation. The design of algorithms to determine the set of routes, the development of simulation models to analyse the working of these algorithms, and the development of a serious game to experience this synchronomodal way of working, is the main focus of this work package.

Approach

Concerning synchronomodal planning and gaming, we consider the following research questions:

- **RQ2.1:** How to generate high quality solutions, using operations research (OR) algorithms, for flexible on-demand planning of SLSP, such that, (i) modalities can be selected short before or even during transport, (ii) the human planner is provided with a number of routes to choose from, and (iii) a modal mix is selected such that costs and CO2 emissions are minimized [7], while the service level of SLPS is preserved?
- **RQ2.2:** How to support the consolidation of shipments in a synchromodal transport setting (both consolidation of LTL shipments in one container as well as FTL shipments on barge and rail transport) and how to share the costs savings among the parties involved?
- **RQ2.3:** How can information on historic job patterns be used to improve the planning of transport and consolidation of shipments?
- **RQ2.4:** How can real-time information (e.g., regarding traffic congestion, delayed deliveries, broken locks) be used to adjust the planning dynamically [9] of SLSP (e.g., route planning, or smart bundling) [11,12,14]?
- **RQ2.5:** How can serious gaming and simulation extend and complement the planning techniques by bringing “the human in the loop”, and lead to a “mental shift”[6] of 3PLs and shippers towards synchromodality?

We apply different research methodologies to answer these questions.

The **first question** (RQ 2.1) will be answered using a combination of operations research techniques and simulation modelling. For each incoming order, a vast amount of routes, connecting the origin with the destination over different hubs, legs, and modalities, is possible. However, a significant amount of these routes is unlikely to yield the optimal solution. Hence, an efficient algorithm does not need to enumerate all routes, but needs to search for a set of promising routes (that differ enough from each other to provide flexibility to the human planner) in an efficient manner.

The **second question** (RQ2.2) will also be based on a combination of operations research techniques and simulation modelling. Models will be developed for different consolidation schemes: for both LTL and FTL shipments as mentioned before, for real-time matching of new requests with previously constructed schemes, but also to support scheduling decisions of orders in anticipation of future requests that might be combined with these orders (postpone transport). Consolidating shipments from different shippers might require negotiation about, e.g., price and delivery time. To support this, pricing and gain sharing mechanisms will be developed based on game theory.

The **third question** (RQ2.3) will also be based on a combination of operations research techniques and simulation modelling. Specifically, statistical methods and data mining techniques will be used to discover order patterns. The benefit of having this information available in our planning will be evaluated using simulation.

The **fourth question** (RQ2.4) will be based on a combination of transaction data analysis (where/when did the freight come from and where/when it should be shipped, what should be the delivered service level level), logistic infrastructure network data (real time information on network events), and dynamic planning techniques.

The **fifth question** (RQ2.5) will be focused on compensating the limitations of the above automated planning techniques. In many real-life planning situations, the decision-making process cannot be fully automated. In such situations, the experience and domain knowledge of a human planner, in interaction with the system, is critical. To gain experience with and to improve our performance in

such situations, which can be classified as visual analytics activities (i.e., assessment, planning or decision-making), serious games can be helpful. Through the use of serious games, we intend to replicate real-life decision making situations through decision scenarios, in which the planning techniques (developed within the frame of RQ2.1 till RQ2.4) are embedded in a software system (developed in collaboration with Activity 3) and are used as decision support [28]. The human planner is interacting with this planning environment when dynamically planning transportation requests in a synchromodal fashion. Thus the game also becomes an interface and front end for testing and validating this system. We want to put emphasis on testing our decision scenarios in practice with domain experts (i.e., human planners) at a very early stage. Successful field tests of decision scenarios are an excellent way to speed up the design of the game and to expedite the adoption of the planning techniques imbedded in the software prototype in practice. This will require the conceptual design a ‘decision room’, consisting of new and flexible interfaces and visualizations of planning dashboards as starting point. Their experimental implementation will be tested by the game users from an early stage (i.e. we are adopting a user-centred design), to confirm the that new interfaces/visualization techniques respond well to changing demands, and offer the required narratives that inform users about relevant spatio-temporal patterns for the planning process.

Research on serious games for decision-making that are used as interactive instruments in a ‘Visual Analytics’ setting include:

- Research on game mechanic models, game story models, game aesthetic models and game environment models tailored for decision-making with respect to synchromodal planning.
- Research on the use of interactive and dynamic graphic representations for spatio-temporal data in serious games.
- Research on the use of synthetic decision room environments for decision support in a Visual Analytics setting.
- Research on how serious games, as an interaction instrument between the planning system and the human planner, can create feedback information for the real time (in game) configuration of analytical reasoning techniques, to enhance rational and multi-perspective decision-making. Research on technology for capturing the decision-making process and how this captured data can be used as input data in a feedback loop within the serious game.

Planning:

2013-2014

- Start of activity by reviewing the relevant literature on transportation planning, consolidation and gain sharing in transport, logistic simulation, and serious gaming techniques.
- Receive education on methodological and conceptual issues related to this research methodology.
- Develop basic synchromodal planning algorithms to support offline as well as online and (nearly) real-time decision making.
- Develop a quantitative model that characterizes the relations between shipping patterns, logistics costs, logistic service levels, greenhouse gas emissions, and commercial benefits of LSPs.
- Develop in collaboration with consortium partners scenarios as first step in the design of the serious game environment.
- Deliver a report for Dinalog on techniques that are relevant in synchromodal planning in the

above-mentioned areas, which also includes a detailed description of the complete research approach for the remaining part of this activity (and PhD project).

2015

- Improve the synchromodal planning algorithms by integration with (i) static and dynamic data sources, (ii) dynamic pricing mechanisms, (iii) business rules for consolidation of shipments and costs and gain sharing, and (iv) forecasting methods for transportation requests and shipment prices, to be used for decisions regarding consolidation.
- Validate the performance of the improved algorithms through simulations on real data provided by the partners.
- Design appropriate interfaces and information visualization for the previously defined decision scenarios, and validate them with domain experts.
- Design a first version of the serious game focusing on the game mechanic, story line, and aesthetics.

2016

- Finalize game design in which both dynamic planning and simulation techniques are integrated. This activity should be closely coordinated with the developments in Activity 3, as the system and services developed in there are (i) based on the algorithms designed in this activity and (ii) will be used here within the gaming environment. Eventually the game environment will have the role of front-end for the system architecture designed during Activity 3.
- Investigation of the performance of the synchromodal planning algorithms and user interfaces, by means of the serious game, in practice.
- Complete PhD thesis.

Work distribution:

Much of the work in this WP is done by the PhD candidate and senior researchers. Primary supervision of the PhD candidate is done by the promoter Prof. J. van Hillegersberg and promotor-assistants, Dr. M.E. Iacob and Dr. M.R.K. Mes. Dr. M.R.K. Mes will also act as WP leader. The investigation of applications of serious gaming to synchromodal planning will be performed in collaboration with Dr. J. de Heer, director of the TXchange lab, which will act as co-supervisor of this PhD candidate. The candidate will be hosted by both the IEBIS group and TXchange. All consortium partners are involved in input on research direction, participation in real-life experiments and involvement in data gathering/analysis. We will also define graduation thesis topics in this area with the aim of also employing MSc students to conduct research within this work package.

MSc projects are used to link the scientific content of the project to practice. Students will be active in several areas: the exploration of the field (via case studies in logistics companies), the definition of planning scenarios (in collaboration with domain experts), gathering and analysis of planning data, and the actual testing/validation of methods developed in this work package within companies. Each year 3-4 students will write their Master thesis on a topic from this WP. Students will be selected from the existing MSc students in IEM (Industrial Engineering Management) and BIT (Business Information Technology) at the University of Twente.

Expected results/deliverables/milestones:

- Sychromodal planning algorithms.
- Decision making scenarios.
- Serious game for sychromodal decision making.
- PhD thesis.
- 4-6 MSc theses.
- 6 scientific papers.

Activity 3: Architecture & Services

Description:

Traditional ICT support for connecting partners in logistic networks has been limited to (often cumbersome) static horizontal and vertical integration of enterprise systems. The ICT links established are usually limited to coordination and control at the operational level in the context of fixed collaboration patterns. This activity focuses on the design and implementation of an ICT platform architecture to support effective and innovative sychromodal logistics.

Sychromodal Logistics Service Provisioning requires a multiservice provisioning platform that enables providers to offer logistic actors new bundled services across existing infrastructure networks and infrastructure services. The platform should hide the heterogeneity of underlying infrastructure networks and therefore builds on the data integration as developed in Activity 1. Furthermore, the platform should provide bundled services which are tailored to the current needs of individual actors and their partnerships in the logistic chain. For this purpose the platform integrates infrastructure services that provide sensor, monitoring and traffic information, as considered in Activity 1, as well as planning algorithms and services as developed in Activity 2. Smart bundling of services is based on the (possibly hierarchical) composition of service components [8, 26, 27, 36], such as the mentioned infrastructure services and planning services, and specialized logistic services. The platform takes care of correct composition through application of various interoperability criteria, including criteria for process and semantic interoperability [8, 26,34]. The composition is enacted by the platform with the use of a coordination service that coordinates the interactions involving the service components of a bundled service and the logistic actors subscribed to the service. During operation and based on monitoring services, the platform may adjust an offered bundled service to improve performance or ensure progress of the bundled service execution. In case of a long-running bundled service, the platform may process requests from logistic actors to adjust the bundled service according to new requirements or to include or remove partners in the present service execution. Such dynamic changes normally impact the composition and interoperability, and require runtime analysis and application of runtime models [10, 35]. Since the platform involves or supports the interaction of various commercial actors, it should provide billing and payment services. Finally, the platform should also have lifecycle management services to allow pluggable services to be added, replaced or removed from the platform.

The focus of this work package is on the design and implementation of the platform architecture to support SLSP. The architecture goes beyond what current logistic planning systems deliver in offering support for pluggable components that implement innovative planning algorithms and decision support. Additionally, this architecture represent the back end of a serious management game for decision making for sychromodal logistics. Thus, the architecture work includes the development of

usage scenarios [31] that highlight the innovative features of the platform, definition of the overall architecture, design of platform functions and services (including coordination and lifecycle services), prototype development using new technologies (e.g., SOA [8, 26, 27], Cloud computing [30], Multi-agent systems [9]) and feasibility and usability studies based on the prototype. Furthermore, the architecture is a means to test and implement R&D efforts done in Activity 1 and 2, and as such it assumes a close collaboration between the three PhD candidates. Additionally, the architecture is a research deliverable itself, as it incorporates the idea of combining various Software as a Service offerings [30] into a versatile environment replacing traditional software packages and homegrown systems, and also a means to achieve the valorization of R&D results.

Approach:

With respect to the SLSP platform we consider the following aspects:

- **RQ3.1:** What are the enterprise architecture requirements of logistic companies with respect to an integration platform[7] that realizes (i) the integration with back-office systems, on-board devices, and other data sources, (ii) provides pluggable information services, and (iii) supports SLSP?
- **RQ3.2:** What are requirements of different partners in the logistic chain for pluggable information fusion, business intelligence, and monitoring services, and for decision support services (e.g., real-time planning adjustments) [10, 32, 33]?
- **RQ3.3:** How to handle system, process, and semantic interoperability problems in the logistic network (where such problems depend on the partners' diversity and autonomy, and on the heterogeneity of employed technology/data sources)[8] with interoperability service utilities [25]?
- **RQ3.4:** Which billing/payment/cost-gain sharing services can be offered to partners in the network, which dynamically adapt to changes in operation and market conditions?

The **first question** (RQ3.1) suggests several innovative features of the platform but at the same time seeks to establish the precise requirements of the stakeholders and users of the platform with respect to these features. The research will be conducted by proposing usage scenarios of the platform that highlight its innovative features. The usage scenarios will be incrementally extended and improved through interaction with stakeholders and users, and at the same time requirements will be derived from the scenarios which will be cross checked with the users. We plan at least two cycles of scenario development.

The **second question** (RQ3.2) addresses the problem of establishing and assessing interoperability. We will use the results from the enterprise interoperability community (e.g., IFIP WG5.8, <http://www.ifip-ei.org/>, and the European EI and FIneS clusters, <http://www.fines-cluster.eu/>) and specialise these for the logistic domain. Although enterprise interoperability is still faced with many challenges, by focusing on the logistic domain we can narrow the problem space and come up with dedicated and pragmatic solutions (with potential of generalization to other domains). We assume that most of the technical interoperability problems (in particular syntactic interoperability) can be solved by adopting appropriate standards, and therefore will focus on semantic and process interoperability. Proposed solutions will be incorporated in the design of platform functions and services. Feasibility of the proposed solutions will be tested during prototype development.

The **third question** (RQ3.3) deals with a particularly hard problem: dynamic changes in the platform

environment may decrease the value of the current service bundle offer, or create opportunities for providing added value which cannot be supported by the current service bundle. The research distinguishes between changes which are notified through information services (based on sensing, monitoring, or information subscriptions) and changes which are requested by a user. The former changes require special treatment since they are subject to reasoning errors, time delays and inaccuracy. The consequences of reported/requested changes should then be analysed and a decision should be made regarding a proposal of a new bundled service and corresponding composition and interoperability. The selected proposal, if any, should replace the current configuration while the current bundled service execution is taken over by the new one at an appropriate checkpoint. We will investigate alternative solutions for supporting dynamic changes. A selection will be based on preferences expressed by the industry partners and quality criteria (performance, scalability). The solution will be incorporated in the platform design and its usefulness will be tested in small case studies with the prototype.

The **fourth question** (RQ3.4) will lead to an inventory of available billing and payment services that can be integrated in the platform. Cost-gain services based on sharing, outsourcing or insourcing will also be considered. A challenging goal of this research is to offer such services to partners in the logistic network, which dynamically adapt to changes in operation and market conditions. Selected services in this category will be incorporated in the platform design and included in the prototype.

Planning:

2013

- Starting WP3 by reviewing relevant literature on agile logistic networks, supporting ICT platform architectures, and composition and interoperability solutions for dynamic environments.
- Phd candidate is trained in methodological and conceptual issues (TGS Service Science, SIKS, and other PhD courses).
- Creating a first set of usage scenarios for the SLSP platform.
- Organize sessions with stakeholders and users to collect opinions on the scenarios.
- Analyse the feedback from stakeholders and users, and elicit requirements regarding the platform and make a second version of the scenarios.

2014

- Organize a second round of sessions with stakeholders and users to collect opinions on the revised scenarios.
- Consolidate the scenarios and requirements.
- Perform a gap analysis between functionality required, functionality in use and latest theoretical concepts (with a focus on bundled service provisioning through composition of decentralized service components).
- Collaborate with Activity 1 and Activity 2 to study integration problems and solutions, and develop a first version of the overall platform architecture in consultation with the industry partners.
- Identify service composition and interoperability issues in the architecture, and propose solution directions.
- Organize a workshop with the project partners to discuss solution directions for platform functions and services.
- Write a scientific paper on the SLPS platform architecture, its innovative features, and the

associated research challenges and intermediate results.

2015

- Study dynamicity problems and solutions in collaboration with Activity 1 and Activity 2, and propose approaches for dynamic service composition and interoperability that fit the objectives of and requirements on the SLSP platform.
- Make an inventory of existing billing and payment services, and possibly other financial services, that fit the objectives of and requirements on the SLSP platform.
- Organize a workshop with the project partners to present the second version of the platform architecture and to discuss and select solution directions for additional or modified platform functions and services to cope with dynamicity and billing/payment services.
- Develop a prototype of the platform architecture with, and integrating prototyped components from, Activity 1 and Activity 2.
- Write a scientific paper on the SLPS platform architecture and how dynamicity is supported by the platform.

2016

- Validate results in case studies using the prototype and the game environment (created in Activity 2).
- Publish the main results in scientific journal papers.
- Complete PhD thesis.

Work distribution:

The work in this WP is done by the Ph.D. candidate and senior researchers. Primary supervision of the Ph.D. candidate is done by the promotor Prof. R.J. Wieringa and assistant promotor Dr. M.J. van Sinderen. Dr. M.J. Van Sinderen will act as WP leader. Dr. M.E. Iacob will be involved to contribute to translating the logistics concepts into requirements for the ICT-based SLSP platform architecture and to the validation using the game environment.

MSc projects are used to link the scientific content of the project to practice. Students will be active in several areas: the exploration of the field (via case studies in logistics and IT companies), the gathering and analysis of data (e.g. marketing surveys, transaction data) and the actual implementation of results in companies (also through case studies at in logistics and IT companies). Each year 1-2 students will write their Master thesis on a topic from this WP. Students will be selected by the research team from candidate students enrolled in the BIT (Business Information Technology) and CS (Computer Science) Master's programmes and the TGS (Twente Graduate School) research programme on Service Science at the University of Twente.

Expected results/deliverables/milestones:

- Insight into current state of multiservice provisioning platforms, application integration and service composition and interoperability, and a Synchronodal Logistics Service Provisioning (SLSP) platform to dynamic support logistic networks.
- A proposal for an SLSP architecture and associated services that fulfil the requirements collected from stakeholders in the logistic domain.
- A proof of concept of the SLSP architecture and services in the form of a prototype.

- An evaluation of the architecture and services.
- PhD thesis
- 4-8 MSc theses
- 6 scientific papers.

Activity 4: Valorization

Description:

In this WP we focus on the valorization of findings from WP 1, WP2 and WP3. The objective of the SynchromodalIT project is to further professionalise the logistics sector. This is facilitated by scientific and business developments regarding consumer preferences, business models and concepts and ICT architectures and applications. The results of the project will be translated in working solutions at participating companies and into services that may be provided by new companies. Consortium partners have stressed the relevance of a focus on applications of the scientific results. Hence, we expect good support from consortium partners. In our project we also aim to involve companies from the start using real-life experiments as this may contribute to the widespread use of our results. We envision valorization in several ways:

1. Implementation of models and tools developed

The PhD students and the MSc students will be involved not only in the development of solutions and tools, but also in the implementation of these solutions in practice at the participating companies. Testing and obtaining feedback on solutions and tools is essential for further improving the quality of solutions and tools

2. Support and active encouragement of new ventures

We expect that there will be possibilities to commercialize the data models for multi-modal logistic infrastructure network, and the software we will develop for dynamic planning, big data processing, and data mining. There are also possibilities in the area of setting up new 4C activities as well as consulting, and training (by means of serious gaming) on cross-chain synchromodal logistics. Thus, we plan to organise gaming sessions for the industry, and be present with our results at logistic fairs.

3. Demonstration projects in the near future

We will examine opportunities for setting up demonstration projects in the near future together with partner companies as well as other interested companies.

Gaming and IT tools play a vital role in our project and, in particular, for valorization. Therefore, next to the WP4 leader, the leaders of WP2 and WP3 bear the responsibility for a successful valorization. We do have IT capacity among partners in our consortium and we plan to organize workshops with these companies throughout the project with the aim of:

- Challenging companies to implement concepts and further develop these into demonstration projects.
- Presenting to and discussing with project members regarding IT tools on a regular basis (at least three times per year).

We will develop a valorization plan before the end of 2013, encompassing the activities that we will undertake in the last 3 years of the project. Valorization is one of the indicators of success of our project and therefore the manager of the valorization work package will report quarterly on the progress of valorization.

Planning:

- Start: Q3 2014
- Completion: December 2016

Work distribution:

Prof. J. van Hillegersberg (WP Leader)
Dr. ir. A. Wombacher (representing WP1)
Dr. ir. M.R.K. Mes (representing WP2)
Dr. ir. M.J. van Sinderen (representing WP3)

Expected results/deliverables/milestones:

- Valorization plan in 2013.
- Yearly action plan (to be updated yearly for the next year).
- Progress reports every quarter.

Activity 5: Knowledge Dissemination

Active knowledge dissemination is focused on informing our stakeholders as thoroughly as possible. We intend to disseminate knowledge in the project via the following means:

1. Show progress of work via social media and websites: We will set up a LinkedIn group, and a website containing information and relevant documentation of the project and (interim) project results, such as, demonstrators, on-line games, master theses, and other publications (responsibility: research team).
2. Make results available to practitioners in the Netherlands and Europe in writing: We will publish (intermediate) results in national and international professional magazines (Logistiek.nl, Supply Chain Magazine in the Netherlands but also abroad: Business Logistics in Belgium, Logistik Heute in Germany or via the European Logistics Association ELA). We also intend to develop at least one white paper per work package per year that is focused on practitioners. We will also publish results in periodicals of branch organizations, such as, Transport en Logistiek Nederland (TLN) (responsibility: research team).
3. Organize/participate in practitioner-oriented seminars and workshops: We will organize a seminar for practitioners at least once per year where we will present work in progress with interested organizations. We will furthermore invite consortium partners to progress meetings every quarter to facilitate and discuss knowledge dissemination, to identify progress and to indicate opportunities (responsibility: research team and consortium partners).
4. Make results available in academic journals and proceedings: Researchers will publish results in journals and present results at scientific conferences on operations research/management and enterprise information systems (responsibility: research team).
5. Develop teaching materials: We aim at developing case studies and other teaching/training materials towards the second half of the project. We envision that a first draft of these case studies can be made by MSc students together with their supervisors, as part of their MSc thesis. We also aim at developing written course documentation on synchromodal logistics for Dutch and international higher professional education. This could be used during executive courses, regional, national and international master classes (responsibility: research team).

The WP5 manager will develop a knowledge dissemination plan before the end of 2013,

encompassing the activities that we will undertake in the last 3 years of the project, with a focus on the coming year. This plan will be revised at least once a year.

Planning:

- Start: September 2013
- Completion: December 2016

Work distribution:

Dr. ir. M.J. van Sinderen (WP5 leader and representing WP3)

Dr. ir. A. Wombacher (representing WP1)

Dr. ir. M.R.K. Mes (representing WP2)

Expected results/deliverables/milestones:

- Knowledge dissemination plan before the end of 2013
- Action plan for year 1 (to be updated yearly for the next year)
- Progress reports every quarter
- Annual workshop with interested (partner and non-partner) companies and institutes as well as quarterly meetings with partner companies and institutes
- White papers and professional journal articles
- Educational/training materials, but also including academic teaching cases.

Activity 6: Project Management

This workpackage deals with the management of the research project. This project uses an effective and efficient management structure, to cover structural, financial, technical and organizational issues. The key objectives of this activity are:

- To coordinate and manage the project and the communication between project partners and Dinalog.
- To set-up and manage a repository for project documents for online collaboration.
- To provide overall administrative and technical management of the project.

The project management structure and decision-making structure take the complexity of the project into consideration to implement the project objectives smoothly and efficiently while maintaining adequate flexibility to anticipate unforeseen reorganization of work according to the project progress. More concretely, the tasks falling under this activity are:

- *Administrative management:* University of Twente is responsible for the project management and assigns a project manager for the day-to-day management of the project.
 - A Consortium Agreement will be signed before the beginning of the project where among others intellectual property rights, exploitation rights, confidentiality, decision and change procedures are described.
 - UT is responsible for the reporting towards Dinalog of project progress and financial performance, and maintaining control over project schedule and budget.
- *Financial management:* The University of Twente is responsible for the financial management and assigns a financial collaborator.
- *Risk management:* In the first phase of the project, the project manager and the WP leaders will make a risk analysis to detect unforeseen problems that may hamper the progress of the project, specify main internal and external risks (organizational, technical, legal) and their associated probabilities for a successful completion of the project.

- *Project repository and reporting system*: The manager will use the management tool provided by Dinalog to manage, delegate, collate and report the project progress.

Planning:

- Start: September 2013
- Completion: December 2016

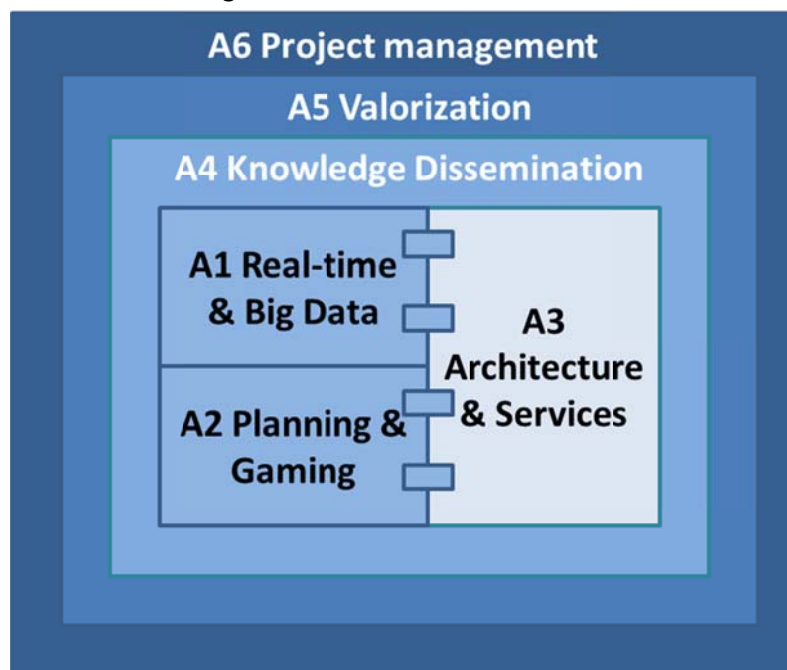
Work distribution:

Dr. M.E. Iacob (project manager)

Expected results/deliverables/milestones:

- Consortium Agreement (after three months)
- Risk Management Plan
- Progress Reports (yearly)
- Cost Statements (yearly)
- Final Report (end of 2016)

The relation between the various activities is shown in the figure below. The knowledge-creation activities A1, A2, and A3 are closely integrated and re-enforce each other, as A3 can also be regarded as a testbed and validation support for A1 and A2, which in turn provide input for A3. A3 also provides the software support for the gaming and can be validated through it. The other activities (i.e., A4, A5, and A6) are support activities, and are meant to facilitate and enhance knowledge creation.



Planning

Below we provide an overview of the overall project plan of SynchromodalIT. Details of the project plan can be found in the individual activity descriptions.

	Q3-2013	Q4-2013	Q3-2013	Q1-2014	Q2-2014	Q3-2014	Q4-2014	Q1-2015	Q2-2015	Q3-2015	Q4-2015	Q1-2016	Q2-2016	Q3-2016	Q4-2016
A1. Data															
A2. Planning & Gaming															
A3. Architecture & Services															
A4. Valorization															
A5. Knowledge dissemination															
A6. Project Management															

Consortium and Project Organization

Research Team

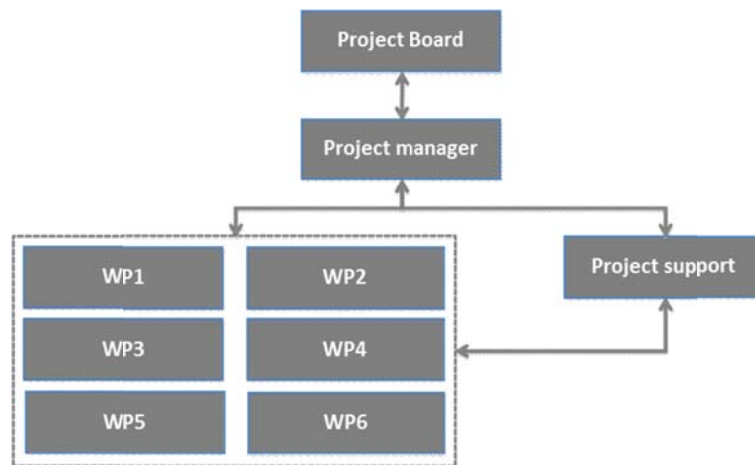
Short CVs of the scientific researchers are included as Annex.

Partner's name	Role and input	Specific competence
University of Twente	Coordinator, project management, input in WP1, WP2, WP3, WP4, WP5	IT design and development, Supply Chain Management and Serious gaming
Dr. M. Iacob	Project coordinator, WP6 leader, co-supervision of all PhD students, Researcher	Enterprise and IT architecture, Service oriented design, Applications in logistics
Prof.dr. J. van Hillegersberg	Promotor of two PhDs students, Leader of the Project board, WP4 leader, Researcher	Operations management & logistics, multi-agent systems, architecture
Dr. ir. M.R.K. Mes	WP2 leader, co-supervisor PhD student, Researcher	Logistics, simulation, multi-agent systems, Transportation Planning & IT
Dr. M.J. van Sinderen	WP3 & WP5 leader, co-supervisor PhD student, Researcher	Service science, Model-driven design, IT architecture, distributed and decentralized information systems, Cloud computing
Prof. dr. R.J.Wieringa	Promotor of one PhDs student, Researcher	Requirements engineering , IT risk assessment, Research methodology information systems engineering
Dr. Andreas Wombacher	WP1 leader, co-supervisor PhD student, Researcher	Distributed data management and data processing, Big Data, Service oriented architectures,

		Workflows
PhD student (vacancy)	Researcher	Real-time & Big Data
PhD student (vacancy)	Researcher	Planing & Gaming
PhD student (vacancy)	Researcher	ICT architecture for logistic service platform

Project organization

The project is coordinated by University of Twente and supervised by a project board. We have based our project organization on Prince II project management principles. We defined the following structure for the project:



The project board consists of two representatives of the participants (to represent the user perspective), a representative from Dinalog (to represent the business perspective, i.e. the extent to which goals are met). Furthermore the project board consists of a scientific member representing science (prof.dr. van Hillegersberg). The project manager reports to the project board. Details of the organizational roles described above are further described below.

Organization	Team lead	Members
Project Board	Prof. J. van Hillegersberg	Representative company 1 Representative company 2 Representative University of Twente Representative Dinalog
WP1	Dr.ir. A. Wombacher	Prof.dr. J. van Hillegersberg Dr.ir. A. Wombacher Dr. M.E. Iacob Vacancy (PhD student)
WP2	Dr.ir. M.R.K. Mes	Prof.dr. J. van Hillegersberg Dr. ir. M.R.K. Mes Dr. M.E. Iacob Vacancy (PhD student)

WP3	Dr. ir. M.J. van Sinderen	Prof.dr. R.J.Wieringa Dr. ir. M.J. van Sinderen Dr. M.E. Iacob Vacancy (PhD student)
WP4	Prof. J. van Hillegersberg	Prof. dr. R.J.Wieringa Prof. J. van Hillegersberg Dr. ir. M.R.K. Mes Dr. ir. Marten van Sinderen Dr.ir. A. Wombacher Dr. M.E. Iacob
WP5	Dr. ir. M.J. van Sinderen	Prof.dr. J. van Hillegersberg Prof. dr. R.J.Wieringa Dr. ir. Marten van Sinderen Dr. ir. M.R.K. Mes Dr.ir. A. Wombacher Dr. M.E. Iacob
WP6	Dr. M.E. Iacob (Project manager)	Dr. M.E. Iacob

The teams of WP1, WP2 and WP3 meet at least every quarter to discuss progress and achievements and to exchange information. This information is then used for the project board meetings that are planned shortly after the project meetings.

C. Evaluation and Monitoring

Evaluation

We will monitor and evaluate the progress of this project within the university in line with regular evaluation processes, in work group meeting and in the project board. We will submit a yearly progress report to Dinalog.

Each PhD project follows the evaluation process that is standard at universities. For each work packages we organize a meeting every quarter where we discuss progress of each of the projects and the extent to which the results have been/will be achieved, as well as issues such as delays or changes in plans. This quarterly meeting also ensures that relevant information is shared, in particular with respect to empirical data for case studies, and tools that can be implemented and facilitate the optimal collaboration between the three PhD students (as explained in the descriptions of the first three project activities). The progress information resulting from these meetings is one of the inputs for the project board meeting. Consortium partners are also invited for these progress meetings to check the extent to which project progress and deliverables keep being aligned with the interested of the consortium.

As indicated under 'organization' above we will set up a project board with representatives from the involved companies and the university, and we will invite a director from Dinalog. The project board meets 4 times a year shortly after the quarterly project meetings. The key role of the project board is to ensure that the Dinalog objectives are met and to discuss proposed schedule and plan changes. In each work package, the work package leader and the PhD student involved are responsible for developing a project plan that includes milestones. For each work package we plan to set up four

key indicators which will be used to monitor and evaluate the of the project plan: a financial indicator, a schedule adherence indicator, an achievement indicator and a valorization indicator. The financial indicator identifies the extent to which the financial budget and resources budget are met. The schedule adherence indicator identifies to which extent the milestones defined in the project are actually met and whether delays are expected in meeting future deadlines. The achievement indicator identifies to which extent the deliverables identified in the work package project plan are achieved. The valorization indicator focuses on identifying opportunities for generating new business. These opportunities are then discussed with the project board (see part E below as well).

Every quarter, the work package leaders write a brief report with a description of the four indicators incorporated, which will be used by the overall project leader in the project board. Every progress report will contain a section with input from the consortium partners on progress to evaluate expected added value for practice from the perspective of consortium partners.

D. Valorization and Implementation Strategy

Valorization and knowledge dissemination

Project Valorization

We have a consortium of industry-leading companies that help to develop best-in-class concepts and tools. We actively support the application of concepts and tools among consortium partners and the development of new ventures based on management games and software services developed in SynchromodalIT. IT consortium partners will be encouraged to develop and market commercial software based on the results of this project. We will apply knowledge developed in this project through amongst others MSc student thesis projects in logistic companies and development of training/teaching materials.

Valorization is a key aspect of our project. To emphasize this we have defined a separate valorization work package. The progress of valorization is captured for WP1/2/3 by making it an explicit evaluation/monitoring indicator for these work packages (as described above). We expect that there are several opportunities for generating new business based on this project. Based on the defined deliverables we expect that at least 2 such new venture initiatives can be started. Where applicable we will make use of Dialog incubator possibilities as much as possible.

Valorization is further described in WP4.

Knowledge Dissemination

We intend to disseminate our knowledge via several media. We will set up a LinkedIn group and a project web site where those interested can follow the endeavours of the project. We will organize events, where practitioners and academics can meet. We have quarterly project team meetings where both researchers and companies meet to discuss progress but also exchange knowledge. We will furthermore develop written materials for academic purposes and for training/educational purposes, both focused at practitioners and at students. Knowledge dissemination is further described in WP5.

Implementation

Implementation pertains to applying and using models, concepts and tools developed in the project.

First and foremost, PhD students and their supervisors are involved in implementation. In the beginning of the project the emphasis will be put on analysing the current situation. Once methods and tools have been developed, PhD students will test and apply their findings in practice. Implementation of project results will also take place via MSc projects. Student projects will focus on specific situations of companies, probably dealing with a variety of logistics planning, control and decision making, and with information issues. In these projects we will identify issues and apply knowledge developed in the project and receive feedback on what works and what does not. Field-testing is essential to developing workable solutions and facilitates their adoption. We have broad experience in our research team with applied research and collaboration with industry. We furthermore have a strong consortium of best in class companies at our disposal to help with implementation issues.

We will perform pilot projects with our consortium partners as a start but we expect to extend this to other partners as well. Consortium partner companies have priority and preferential treatment but the test of certain concepts and tools may require a broader application than just the consortium partners. The first projects with companies will be exploratory in nature. Only in year 2 and onwards we expect to be able to start testing and implementing ideas in practice. For that reason we will develop a detailed implementation plan towards the end of the first project year.

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Annex Short Researcher CV's

Jos van Hillegersberg

Short CV

Jos van Hillegersberg is head of department and professor of Business Information Systems at School of Management & Governance, University of Twente. He is program director of the Business Information Technology BSc and MSc programs. Before joining the University of Twente in 2005, he was on the faculty of the Rotterdam School of Management, Erasmus university for 15 years, working on component based software systems, IT management, global outsourcing and agent systems for supply chains. He is interested in the effects of new IT services on supply chain integration, and studies the Development and adoption of inter-organizational systems from a business and socio-technical perspective.

He is currently involved in several research projects studying new ICT concepts for agile logistics business networks. He is leading the ICT work package in the Dinalog 4C4More project. He was project and theme leader of the nationally funded projects Transumo (transition to sustainable supply chains). As project leader of the Transumo Distributed Planning and Optimization with Multi-agent technology he initiated and conducted several research projects with the port of Rotterdam, Shell and Merba on the benefits of multi-agents for sustainable logistics. Other projects he participated in are Software Mass Customization, the EU projects ECOSPACE (on future workspaces for virtual collaboration) and Myotel (on adoption of wireless sensor networks for Healthcare). He also worked for several years in business. At AEGON he was component manager for the setup of an Internet Bank. He worked at IBM on artificial intelligence and expert systems. He is currently running projects on improving collaboration in business networks using innovative ICT such as agent technology.

Education: Leiden University, Computer Science (MSc, 1991); Erasmus University Rotterdam, Meta-modelling based integration of OO (PhD, 1997)

5 recent publications

1. Folmer, E., P. Oude Luttighuis, and J. van Hillegersberg. 2011. "Do Semantic Standards Lack Quality? A Survey Among 34 Semantic Standards." *Electronic Markets*: 1–13.
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Maria-Eugenia Iacob

Short CV

Maria-Eugenia Iacob is currently assistant professor at the department of Information Systems and Change Management, at the University of Twente. Previously she worked as scientific researcher at Telematica Instituut (2000-2006). She holds a Ph.D. degree in Mathematical Analysis from the University Babes-Bolyai of Cluj-Napoca, Romania. She has done research in the areas of (enterprise) information systems architecture design and analysis, service-oriented architectures, model driven development, model transformations, e-services architectures, e-government, business process (re)engineering and management, and business modelling.

Her research interest include:

- Business Process Integration and Management
- Data and Process Interoperability of distributed enterprise applications, inter-organizational integration
- Enterprise Architectures: Methods, modelling and (quantitative) analysis
- Business, Goal, and Value modelling, electronic commerce and networked business
- Business Intelligence and Data Models
- Service-Oriented and Model-driven Design
- Applications of all the above in logistics, healthcare, e-government, etc.

5 recent publications

1. M.E. Iacob, L.O. Meertens, H. Jonkers, D.A.C. Quartel, L.J.M. Nieuwenhuis, M.J. van Sinderen, From Enterprise Architecture to Business Models and back, To appear in the *Software and Systems Modeling Journal*, Springer, 2013.
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Martijn Mes

Short CV

Martijn Mes is an assistant professor within the department Industrial Engineering and Business Information Systems at the University of Twente. He holds an MSc in Applied Mathematics (2002) and did his PhD at the School of Management and Governance, University of Twente (2008). After his PhD defense, Martijn worked at Princeton University as a visiting professor for half a year. Martijn provides the following courses: Simulation, Warehousing, Management of Technology, Supply Chain and Transportation Management, Stochastic Models for Operations Management, Project Process Control and Production Management, Project Production and Logistics Management. His research involves multi-agent systems (MAS), pricing and auctions in freight transport, behavioural issues in freight transport, dynamic vehicle routing problems (VRP & DVRP), AGV routing, ranking and selection problems (R&S), optimal learning, approximate dynamic programming (ADP), simulation optimization, discrete-event simulation, and simulation of logistic systems.

5 recent publications

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Marten van Sinderen

Short CV

Marten van Sinderen is associate professor at the department of Information Systems of the University of Twente. He is also research manager in the area of Service Architectures and Health Applications, on behalf of the Centre for Telematics and Information Technology, the ICT research institute of the University of Twente. His research activities cover distributed and decentralized information systems, with special attention to smart services and model-driven development, and applications in the health, logistics and energy domains. He acted as general and program chair of several conferences, including EDOC 2005 (on Enterprise Computing), ICE-B 2007 (on e-Business), CLOSER 2010 (on Cloud Computing and Service Science), and SensorNets 2012 (on Sensor Networks). He is currently steering committee chair of the IEEE International EDOC Enterprise Computing Conference. He participated in various European initiatives/projects including MODA-TEL (Model Driven Architecture for Telecommunications Systems Development and Operations, IST 37785), E-NEXT (Emerging Networking Experiments and Technologies, IST 506869), AMIGO (Ambient Intelligence for the Networked Home Environment, IST 004182), and SPICE (Service Platform for Innovative Communication Environment, IST 027617). He was project manager of the Dutch Freeband A-MUSE project (BSIK 03025) on model-driven service design for context-aware mobile applications, and currently leads the Dutch GenCom U-Care project (IGC0816) on user-tailorable healthcare services for the home environment.

5 recent publications

1. Iacob, M.E., M.J. van Sinderen, M. Steenwijk, and P. Verkroost (2013). Towards a reference architecture for fuel-based carbon management systems in the logistics industry. To appear in *Information Systems Frontiers*, 2013.
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Roel Wieringa

Short CV

Roel Wieringa is Chair of Information Systems Engineering at the University of Twente (<http://www.cs.utwente.nl/~roelw>). His research interests include requirements engineering, IT risk assessment, modelling and design of collaborative networks, and design research methodology for software and information systems engineering. Among his recent projects in these areas are STW-funded projects on value-based security risk mitigation (VRIEND), policy specification for mobile security (VISPER) and policy-based intrusion detection (IPID), and the NWO-funded projects on value-based IT alignment (VITAL), coordination process correctness (COOP) and adaptive configuration of value networks (VALUE-IT). Roel has written over 300 publications in these fields and has written two books, *Requirements Engineering: Frameworks for Understanding* (Wiley, 1996) and *Design Methods for Reactive Systems: Yourdon, Statemate and the UML* (Morgan Kaufmann, 2003), and currently preparing a book on *Design Science Methodology* that will appear with Springer in 2014. He is serving regularly on the program committees of conferences on Requirements Engineering (RE and REFSQ), Advanced information systems engineering (CAISE) and conceptual modelling (ER), and has organized some of these conferences in the past, acting as general chair or program chair. He has been associate editor in chief for requirements engineering of IEEE Software from 2004 to 2007. He serves on the board of editors of the Requirements Engineering Journal and of the Journal of Software and Systems Modeling. Roel Wieringa has been head of the Computer Science Department of the University of Twente (2009-2012) and scientific director of the Dutch national School for Information and Knowledge Systems (SIKS, www.siks.nl) (2006-2011).

5 recent publications

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Andreas Wombacher

Short CV

Dr. A. Wombacher is an assistant professor at the Database Group of University Twente and in the management team of CTIT since Sept 2007. He did his master and Ph.D. degree at the Technical University of Darmstadt. He gathered professional experience at IBM (Germany), the Integrated Publication and Information Systems Institute (IPSI) of Fraunhofer Gesellschaft (Germany), the University of Twente (Netherlands), and the Swiss Federal Institute of Technology in Lausanne (EPFL, Switzerland). His research interests are in the area of distributed data management and data processing with a focus on sensor networks, service oriented architectures, and workflows. He has published more than 100 papers and has been involved in several organisation committees. Andreas Wombacher has participated in several EU projects.

5 recent publications

1. Li, Chen and Reichert, M. and Wombacher, A. (2011) Mining business process variants: Challenges, scenarios, algorithms. *Data and knowledge engineering*, 70 (5). pp. 409-434.
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