Summary

Transportation companies often find that their day-to-day transportation execution does not conform to the transportation plan that they made in advance. To a large extent this is caused by the fact that the software that aids in the creation of transportation plans, does not take into account the real-world complexity of transportation and logistics. Rather, it uses approximations and abstractions that do not do justice to that complexity. As a consequence the transportation plans that are generated by transportation planning software often lead to violated time windows, unnecessary delays, underutilized transportation capacity, etc. The real-world complexity of transportation planning is caused by the high level of detail that is required to get executable plans, the size of the instances as found in reality, and the large volumes of data that must be collected and processed to gather the information required to create the planning. A particular source of detail is stochasticity and time dependency of data, which is ignored by modern-day transportation planning software. To automatically compute transportation plans that have a better match with day-to-day transportation execution, transportation planning software must be developed to deal with these sources of complexity.

Therefore, the goal of this project is to develop the algorithms and software that can handle time-dependent, stochastic, planning problems, based on high-volume information. We will particularly focus on the complexity that arises when integrating planning problems and stochastic dependencies that arise in Cross Chain Control Centers (4C), because in a 4C: i) the required real-life detail increases, ii) problem instances are considerably larger, and iii) pressure on response time increases as more communication is required.

The project is separated into four main work packages. The first work package concerns the development of 4C scenarios together with the project's industry partners and the evaluation of the effectiveness of the developed software in the context of these scenarios. The second work package ensures the integration of the two main software components, which are developed in work package three and four: efficient algorithms for time-dependent, stochastic, planning problems; and information aggregation techniques that can efficiently calculate the time-dependent distributions from large volumes of data.

By developing general 4C software that improves transportation plans, we expect that additional business can be generated for the Dutch transportation industry. In particular, our software facilitates the creation and expansion of 4C organizations, as dedicated planning software is an important enabler for such organizations. We also expect that additional business can be generated for information providers, transportation software developers and Dutch transportation companies that can work more efficiently because of our software.

The project is highly innovative due to the fact that, to the best of our knowledge, no modern transportation planning software takes time dependency and stochasticity into account. At the same time, no general 4C software exist. This will make the software that is developed in this project, the first software to truly enable off-the-shelf 4C transportation planning and control.

The results of the project will be directly implemented at our logistics project partners. The results that are achieved by our project partners will be used as a motivation and business case towards other companies. In addition, the generic software and knowledge about how to apply the software to practical usage scenarios, will be marketed as solutions by our software and consultancy project partners. In this way our project partners will be ready to rapidly implement 4C solutions wherever they are necessary.

A. Orientation and Project Goals

Motivation

In practice companies are faced with a disconnect between their transportation planning and day-to-day transportation execution. This gap is caused by the tension between the complexity of the planning problems and the available response time for planning software to compute a planning. The complexity is due to the real-life detail that is required to get executable plans, the size of the instances as found in reality, and the large volumes of data that must be collected and processed to gather the required information. An important part of the real-life detail is stochasticity of data, where stochastic travel times is a prominent example. A classical way to cope with stochasticity is by adding buffer times inside the planned routes. This is difficult though as it may still be too little, or actually too much, making that stochasticity in practice leads to violated time windows, unnecessary delays, underutilized transportation capacity, waiting times, etc. Many Logistics Service Providers (LSPs) furthermore act across modalities, and the gap described above is increased for synchromodal transport, because handling stochasticity, like for travel times or load sizes, becomes more difficult when being faced with the modality choice carriers have for each transportation leg in synchromodal transport [1]. Finally, the gap gets even more important in a 4C as: i) the required real-life detail increases, ii) problem instances in a cross chain environment are considerably larger, and iii) pressure on response time increases as more communication is required.

In order to bridge this gap and to efficiently and effectively integrate transportation planning and execution, two important problems must be solved:

1. The complexity of transportation planning must be handled with efficient algorithms in order to get executable plans within acceptable response times.
2. The complexity of information aggregation from high-volume information sources (such as GPS dongles) into relevant planning information must be handled with efficient information aggregation software.

In this research project, we will solve these problems, by developing the algorithms and software that can handle time-dependent, stochastic, planning problems, based on high-volume information. We will particularly focus on the complexity that arises when integrating planning problems and stochastic (transshipment) dependencies that arise in Cross Chain Control Centers (4C) [2] and synchromodal transportation. We will test the algorithms and software in the real-life environments of our LSP project partners.

Integrated Transportation Planning and Execution

The transportation problems we will study will at least cover transportation planning and execution problems found at the LSP project partners, where we will extend the problems to match what one can expect to encounter in a 4C both in complexity and instance size. Using the different transport modalities of our LSP project partners, the modality choices for transportation legs of synchromodal transport will be included. This combination will constitute a formidable challenge, where we nonetheless believe we have excellent chances of success through the combination of project partners that will provide travel time data and knowledge, transportation data and knowledge, logistics consulting knowledge, and the availability and knowledge of software for combinatorial optimization and transportation planning and execution. We will develop algorithms used in transportation execution that will handle stochasticity by efficiently and smartly updating plans to accommodate new information, like actual travel times or load sizes. These are obviously of great practical value, but are insufficient as decisions taken now will have future consequences. We will therefore also develop algorithms used in transportation planning that will use the stochastic information, together with the rich set of other real-life data, to generate plans that strike the balance between being robust and cost-efficient. These planning algorithms should explicitly aim to take decisions that will reduce the amount and severity of corrections needed in transportation execution. It is such an integrated approach to transportation planning and execution that is expected to bring the full benefit that logistics companies seek. We expect to be using a combination of technologies that includes, but probably will not be limited to, Mixed Integer Programming, Constraint Programming, Large Neighborhood Search, Approximate Dynamic Programming , Machine Learning, and Simulation [3,4,5,6,7].

Information Aggregation

In order to create a planning, data must be aggregated from different sources that potentially generate large volumes of data related to a large number of instances. This data must be aggregated into information that can be used for planning. For example, TomTom aggregates continuous data about GPS locations of transportation resources into stochastic time-dependent travel times. Similarly, these GPS locations can be aggregated into real-time stochastic estimates of arrival times. To enable the aggregation of such high volumes of data from different sources, an efficient software infrastructure must be developed, based on Complex Event Processing [8]. This software must take into account that it is undesirable to share all information between all partners for reasons of efficiency and confidentiality. To facilitate selective information aggregation, multiple views on the information will be created [9], by automatically correlating the information with the transportation plan and subsequently aggregating it into business events that are meaningful on the level of the transportation plan. In addition, some sensory events might be missing, due to loss of communication because of limited coverage of the mobile communication network or other exceptional reasons. Methods to deal with incomplete and exceptional events need to be analyzed and adapted to the transportation domain [10].

Relation to Dinalog´s innovation themes

As described above, the project aims to develop software and algorithms to deal with the complexity of 4C and Synchromodal Transport, both leading themes for the National Innovation Program.

To the best of our knowledge, this project is the first attempt at building generic, configurable, software for 4C. Such software will greatly improve the ability to create new cross-chain control centers. Software is an important enabler for such centers, because they are typically set up in such a way that they do not have own assets, but rather coordinate assets of other transportation companies. Consequently, the knowledge that they bring, for example in terms of planning algorithms, and the software that implements that knowledge is their most important asset.

The LSPs that participate in the project already operate across multiple modalities. For example, Jan de Rijk Logistics has both road and rail assets and also uses air, Ewals Cargo Care uses a combination of road, rail, and sea, and Quintiq is exposed to all transportation modalities through their customer base (including barge operators and inland terminal operators). The LSPs thus must connect to different modalities and adjust their planning to real-time events originating from those modalities. To make the software as generically applicable as possible, the project also specifically considers synchromodality in 4C.

Objectives and goals

The main goal of the DAIPEX project is to develop generic, configurable, planning software for synchromodal 4C that can handle:

1. the increased complexity of 4C in terms of the number of instances that a 4C must deal with and planning improvements by specifically taking into account stochasticity and time dependence of travel times.
2. the efficient aggregation of information for transportation planning from high data volumes from multiple sources involved in a 4C.

In particular, the transportation planning software must handle the complexity of 4C with respect to these points, while still computing a transportation plan within a timeframe that is acceptable to transportation planners.

The software must be generic, which we measure as: applicable to typical transportation planning problems in a 4C, while demonstrably reducing development time and cost compared to conventional (non 4C-specific) transportation planning software. In the context of this project, the software must be applicable to 4C usage scenarios of the LSPs involved in the project. The scenarios that will be addressed, will be determined in detail during this project, but will at least involve:

- co-planning of transportation between transportation partners.
- synchromodal planning of transportation.

At the end of the project, the software must not only demonstrate its applicability to planning problems of project partners, but at the same time a valorization plan must be ready for further exploitation of the software in 4C.

The transportation planning and execution software that will be developed in the context of this project allows carriers to more accurately determine what transportation volume they are able to handle and to better use their capacity, which in turn allows them to sign new customers, while previously they may not have been able to do so in a profitable way. Shippers in turn will benefit through cost reductions by means of improved transportation plans that take stochasticity and time dependence into account. By making this possible, we aim for a profit increase at our transportation partners of 5-15% within 2-5 years after the first implementation of the transportation planning software.

Expected results

By developing the next wave of transportation planning and execution software, the DAIPEX project will have impact both on our project partners and on the Dutch economy as a whole.

There are several, interrelated, parts of the economic impact.

- For LSPs. Based on past experience of Quintiq in the development of transportation planning and execution software, we estimate a profit increase of 5-15% mostly due to attracting more business. With margins under pressure this can be more than helpful in being profitable or even in surviving.
- For companies providing travel time data. There are tens of thousands of potential customers around the globe (carriers and shippers). An estimate from TomTom's practice is that each end user doing execution will spend €150K per year, so that 1000 customers represents €150M per year, making 1.5% of the target 2020 GDP contribution mentioned above.

- For software and consulting firms. Practice shows that transportation planning and execution projects range from approximately €200K-2M in software and services. It should be possible to get to the abovementioned 1000 customers over a period of 4 years, implying 250 customers per year, making €50-500M, another 0.5-5% of the target 2020 GDP contribution.

The impact on our project partners depends on the specific link in the transportation value chain that they represent.

- Carriers will benefit by being able to attract business that can profitably be handled in the context of a 4C, but not by a single carrier.
- Shippers will benefit through cost reductions by means of better planning.
- The expected result for TomTom is that the project opens up a whole new market for information aggregation software, in which they already play an important part (viz. their HD traffic solution that aggregates real time traffic information from GPS coordinates that are continuously collected from individual), next to their well-known personal navigation systems.
- For software companies and consulting firms like Quintiq, the expected result is to be able to sign new customers (carriers and shippers), providing them with software tools and/or consulting expertise that support the improved process of transportation planning and execution.

Relation to government policy

In achieving the results outlined above, the DAIPEX project is directly linked to the ambition formulated by the Dutch government to make The Netherlands in 2020 the European market leader in controlling flows of goods passing through one or more European countries [11], with the goal to boost the Dutch GDP in supply chain control and related logistics activities from € 3 billion in 2007 to at least € 10 billion in 2020.

Orientation

Currently, many software solutions and algorithms exist for transportation planning (for example [12,13]) and information aggregation (for example [8,14]). This includes software developed by industry project partners (in particular TomTom and Quintiq) and algorithms researched by academic project partners [1,5,6,7,24,25,26,27]. However, current software and algorithms are unable to produce a transportation plan within a feasible timeframe, when dealing with large numbers of transportation instances or stochastic or time-dependent data. In particular, current systems are unable to process the large volumes of data associated with continuous monitoring of GPS locations of transportation resources; use that data to create a stochastic estimate of the expected arrival times; and using these stochastic estimates to determine and continuously update the transportation planning. The DAIPEX project aims to fill this gap. In doing so, it aims to interact with complementary research projects that are carried out within Dinalog and by DAIPEX project partners.

Dinalog projects that are of particular interest for the DAIPEX project are the 4C4More project, the SALOMO project and the Extended Single Window project. The 4C4More project, in which partners of this consortium also participate, aims to develop concepts for 4C. The DAIPEX project aims to build on those concepts, in particular the ICT concepts, and develop them further, by focusing on the development of software for data aggregation and transportation planning and execution. The SALOMO project develops tools to improve collaboration in a supply chain. The DAIPEX project can use these tools as input to develop 4C usage scenarios. The Extended Single Window project aims to facilitate efficient sharing of information. However, while the Extended Single Window project primarily focuses on administrative information, the DAIPEX project focuses on real-time information related to transportation planning and execution. Nonetheless, knowledge about the architecture of the software can be shared and the projects can complement each other.

DAIPEX project partners participate in a large number of related national and international projects. Projects that are of particular interest are: 4C4More (Dinalog), GET Service (FP7), the National Logistics Information Platform (Economische Zaken), e-Freight (FP7), and FREIGHTWISE (FP6). The relation to the Dinalog 4C4More project is described above. Both the National Logistics Information Platform and the e-Freight project aim to develop platforms for sharing administrative logistics information; the National Logistics Information Platform on a national level and e-Freight on a European level. Consequently, these projects have a similar relation to DAIPEX as the Extended Single Window Dinalog project explained above. The FREIGHTWISE project develops ICT solutions for synchromodal transportation. DAIPEX extends this work by focusing on synchromodal solutions in a 4C setting. The GET Service project develops an ICT platform for joint transportation planning and execution. DAIPEX extends this work by focusing on a 4C setting. Of particular interest is the information aggregation component that is developed in the context of the GET Service project. DAIPEX aims to exploit research results from the GET Service project in this area, but extends these research results, by particularly focusing on multi-parameter data correction and data obfuscation.

B. Activities and Work Packages

For the overall project, an iterative user-centered design (UCD) cycle guides the design, development and evaluation of the 4C transportation planning and execution software.

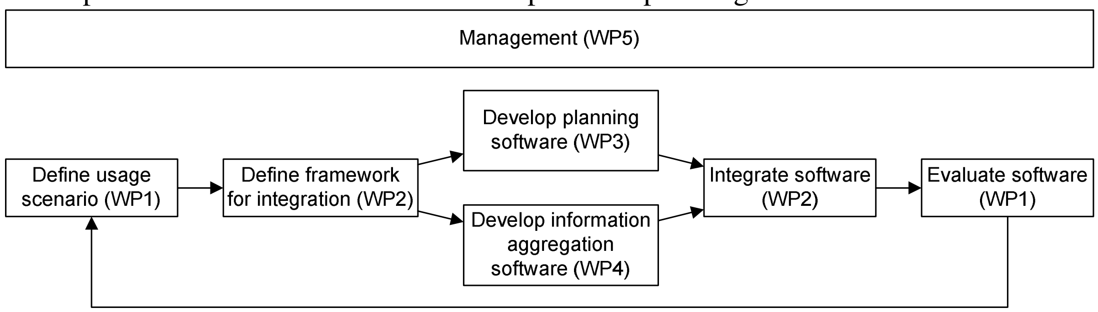


Figure **1** outlines the design cycle and the main design activities. The design is guided by the requirements of end-user organizations, which are explicitly involved to define usage scenarios and software requirements in Work Package 1.

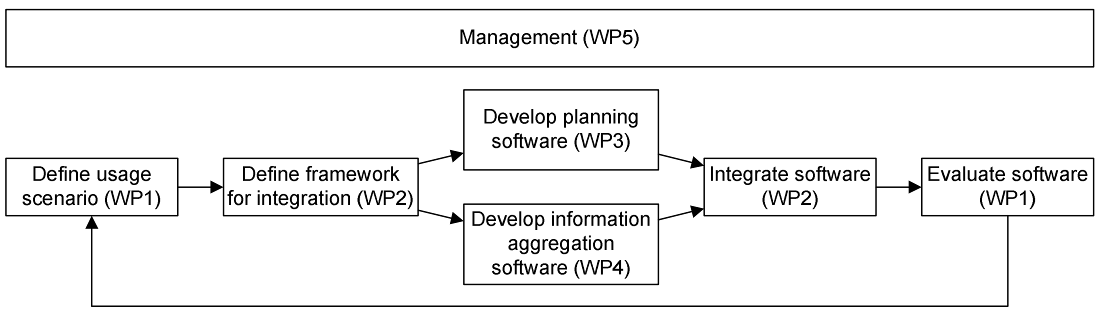


Figure 1. Overall design approach.

The technical research and development activities are structured in two work packages that correspond to the two main goals of the project as outlined above: (Work Package 3) the development of transportation planning and execution software; and (Work Package 4) the development of information aggregation software. The main research activities will be carried out in these work packages. The research approach that will be used to carry out these research activities will be outlined below, where the work packages are described in more detail.

Conform the user-centered design approach, the technical research and development activities are driven by rapid prototyping. The complete cycle from usage scenario analysis to prototyping and end-user testing is done twice. This allows feedback from the end-users in an early stage of the design and development process. Each of the two cycles has an explicit goal with respect to the end-user scenario that must be supported at the end of the cycle and the advanced components that must be completed in the cycle. While the scenarios will be defined in detail in Work Package 1, the first usage scenario will at least cover co-planning of transportation between transportation partners in a 4C, while the second usage scenario will elaborate on this by covering synchromodal (co-)planning of transportation in a 4C.

The integration of the two main components (developed in WP3 and WP4) is ensured in Work Package 2. This work package entails the definition of a framework to govern the development of the components and eventually ensure their successful integration. It also entails the actual integration of the two components.

Below, each work package is explained in more detail.

Work Package 1: End-user studies

Objectives

- Develop practical usage scenarios for (synchromodal) transportation co-planning and execution in 4C.
- Based on the usage scenario's, develop a set of requirements for the transportation planning and execution software.
- Develop a precise evaluation plan, including evaluation criteria.
- Execute the evaluation plan in two iterations as outlined in the overall design approach above.

Task 1.1 Usage scenarios

Usage scenarios are described and analyzed. These usage scenarios are based on real-world case studies and expert interviews with the logistics partners in the project. They demonstrate which business cases are not supported by conventional transportation planning and execution software, but would be possible with advanced 4C transportation planning and execution software. At least two usage scenarios will be described. The first usage scenario will at least cover co-planning of transportation between transportation partners in a 4C, while the second usage scenario will elaborate on this by covering synchromodal co-planning of transportation in a 4C. For both scenarios, the potential benefits for the logistics partner will be quantified (such as cost reduction, transportation time reduction, and attracting additional business). Based on this analysis evaluation criteria will be defined that will drive the evaluation. The result of this task is a report describing the usage scenarios and evaluation criteria (D1.1).

Task 1.2 Requirement analysis

Based on the analysis of the usage scenarios in task 1.1, detailed requirements are established for the DAIPEX system. These requirements are identified and reported by means of a use case analysis (D1.2), which serves as the basis for the actual research and development in WP3 and WP4. Requirements in the following categories will be defined:

- Planning requirements, describing the parameters and expected results of a transportation plan in a particular usage scenario.
- Information requirements, describing the information that is required to compute a transportation plan, given the desired parameters and expected results.
- Technical requirements, describing the requirements concerning the technical architecture of the software and quality of service requirements.
- User interface requirements, efficient interaction between the user and the system is especially important in time-critical applications, such as transportation planning, therefore requirements for the graphical user interface of the software will be identified.

Task 1.3 Evaluation plan

Based on the usage scenarios and evaluation criteria that are defined in task 1.1, an evaluation plan will be established. The evaluation plan serves as a precise guide and scientific approach to evaluate whether the given evaluation criteria are met by the transportation planning and execution software that is developed. The evaluation plan consists both of an approach and precise performance indicators that will be measured during the evaluation (such as loading factor and travel time).

Task 1.4 Evaluation

At the end of both development cycles, end-user tests will be performed in real-world settings to determine whether the system is successful in supporting the usage scenarios that are determined in Task 1.1. These tests will be performed with the logistics partners in the project, according to the evaluation plan that was developed in task 1.3. The results of each test cycle will be described in a report (D1.4.1, D1.4.2).

Planning:

Task 1.1: Month 1-10
Task 1.2: Month 9-12
Task 1.3: Month 13-24
Task 1.4: Month 25-30, Month 37-42

Work distribution:

Task 1.1: TU/e (task leader), Quintiq, Jan de Rijk, Veldhuizen, Ewals, EOV
Task 1.2: TU/e (task leader), Quintiq, Jan de Rijk, Veldhuizen, Ewals, EOV
Task 1.3: TU/e (task leader), Quintiq, Jan de Rijk, Veldhuizen, Ewals
Task 1.4: TU/e (task leader), Quintiq, Jan de Rijk, Veldhuizen, Ewals

Expected results/deliverables/milestones:

Deliverable D1.1 Usage scenarios and evaluation criteria (M10)
Deliverable D1.2 Requirement analysis (M12)
Deliverable D1.3 Evaluation plan (M24)
Deliverable D1.4.1 Report on end-user tests cycle 1 (M30)
Deliverable D1.4.2 Report on end-user tests cycle 2 (M42)

Milestone MS1: Usage Scenarios, Architecture and Early demonstrator (M12)
Milestone MS3: Evaluated DAIPEX System, first iteration (M30)
Milestone MS5: Evaluated DAIPEX System, second iteration (M42)

Work Package 2: Framework and integration

Objectives

- Develop a detailed architecture that governs the integration of the two main components of the system: the transportation planning and execution component (WP3) and the information aggregation component (WP4)
- Develop an early demonstrator to show the current state of the art in transportation planning and control and information aggregation.
- Perform the actual integration of the two main components.

Task 2.1 Develop architecture A detailed architecture of overall DAIPEX system will be designed (D2.1), to govern the development of the system and to ensure that the two main components – the transportation planning and execution component and the information aggregation component - which are developed in WP3 and WP4, can be integrated at a later stage. The architecture will be developed in line with existing architectures. Of particular interest are the architectures that already exist at the partner organization. The interfaces that are identified in the architecture will be standardized in an early stage of the project. This further ensures that the components can be integrated successfully at a later stage in the project. The interfaces between the DAIPEX software and other, existing, software platforms will also be taken into account. In particular, TomTom and Quintiq already have proposed architectures and interfaces for their software and the logistics partners that are involved in the project do as well. The potential integration of these systems must be governed by the overall architecture and standardization of interfaces. *Task 2.2 Early demonstrator* In the first year, an early demonstrator will be developed by integrating existing components that are already in use by project partners. Of particular interest are the information aggregation component that TomTom uses to compute traffic information from continuous broadcasting of GPS coordinates by transportation assets and the transportation planning and execution software that is developed by Quintiq. Also, the transportation execution software that the logistics companies use will be taken into consideration. The goal of the early demonstrator is to demonstrate what is already possible with transportation planning and execution software and with information aggregation software. The goal is also to show what is not yet possible, but will be made possible by the DAIPEX project. *Task 2.3 Integrate components* After the primary components of the DAIPEX system have been developed (in WP3 and WP4), they must be integrated. The integration will be done in this task. Integration will be performed in two phases, corresponding to the two cycles in which the system will be developed and leading to milestones MS2 and MS4. This results in two integrated prototypes (D2.3.1, D2.3.2).
Planning: Task 2.1: Month 1-12 Task 2.2: Month 7-12 Task 2.3: Month 21-30, Month 33-42 At Milestones 2 (Month 26) and 4 (Month 38), the integrated system is delivered. However, Task 2.3 continues beyond these milestones into the evaluation (Task 1.4), because while a system is initially used, problems typically still arise. These problems can be solved in Task 2.3.
Work distribution: Task 2.1: TU/e (task leader), Quintiq, TomTom, EOV Task 2.2: TU/e (task leader), Quintiq, TomTom, Jan de Rijk, Veldhuizen, Ewals, EOV

Task 2.3: TU/e (task leader), Quintiq, TomTom, EOV

Jan de Rijk, Veldhuizen and Ewals are only involved in Task 2.2 to validate the result.

Expected results/deliverables/milestones:

D2.1: DAIPEX architecture and interface standard (M12)
D2.2: Early demonstrator (M12)
D2.3.1: DAIPEX System, first iteration (M27)
D2.3.2: DAIPEX System, second iteration (M39)

Milestone MS1: Usage Scenarios, Architecture and Early demonstrator (M12)
Milestone MS2: Integrated DAIPEX system, first iteration (M26)
Milestone MS4: Integrated DAIPEX system, second iteration (M38)

Work Package 3: 4C transportation planning and execution software

Objectives

- Obtain formal optimization problem descriptions that cover the real-life transportation planning and execution problems as encountered at transportation partners, as well as a selected number of customers from Quintiq's practice.
- Develop and test algorithms that solve the described real-life transportation planning problem.
- Develop and test algorithms that solve the described real-life transportation execution problem.

Research Approach

There is a large body of literature available on modeling and solving realistic vehicle routing problems (VRPs) including the handling of time-dependency and stochasticity. An early survey on stochastic VRPs can be found in [29]. A good recent literature overview both of approaches for VRPs with time-dependent travel times and stochastic VRPs is given in [30]. [30] also provides state-of-the-art approaches to solve VRPs with stochastic travel times, time-dependent travel times, soft time windows, and flexible time windows. [12,31] are other notable examples of research done on realistic VRPs where topics like traffic congestion, time-dependent travel times, and driving hour regulations are studied. For an overview of research done on synchromodality we refer to [1].

Despite this large body of literature, to the best of our knowledge there is no literature available on modeling and solving the problems as we will study in this project. That is due to both the required real-life detail and the required instance sizes to be solved. As such we will need to, considerably, further the current state-of-the-art to successfully solve the problems at hand. Some initial research in this direction is already done by members of the consortium in [32,33,34]. In [32] a MIP model, a Restricted Dynamic Programming approach, and a Scatter Search approach are studied for a real-life load building and routing problem. [33] studies travel time predictions using data from project partner TomTom, tested on a small region in The Netherlands. [34] studies a problem inspired by Quintiq's practice where one is faced with hard time windows and wants to have a certain reliability that deliveries are done on time. The common conclusion of this research is that it holds a lot of promise, but that still a lot of work is needed to make it practically applicable. Consequently, the aim of this work package is to do exactly this.

The work package follows the same iterative approach that is proposed above. Starting with from the usage scenarios and requirements that are identified in Task 1.1 and 1.2, it casts the transportation problems into formal problem descriptions (Task 3.1). It then continues to solve these problems in three stages. In the first stage (Task 3.2) a manual planning application is developed, which helps both to check the result of Task 3.1 and serves as input to the early demonstrator that is developed in Task 2.2. In the second and third stage (Task 3.3 and 3.4) the improved planning solutions are developed. These directly contribute to the integrated system and are evaluated in Task 1.4.

Task 3.1 Define formal problem descriptions

Following Tasks 1.1 and 1.2 formal optimization problem descriptions for the planning and execution problem are developed. These problem descriptions will obviously cover co-planning of transportation between transportation partners in a 4C, but at the explicit request of the LSP project partners will also go into expressing alternative transportation modalities that not only differ in travel time and cost, but also in reliability. Transportation by train for example tends to be slower, but also have less variability, which under certain circumstances is attractive, while under other circumstances is unattractive. Making the right decisions at the right times is deemed difficult as well as crucial. Expected real-life properties of the problem furthermore include, but will not be limited to, a combined load building and routing problem, split deliveries, a heterogeneous fleet, site resources with varying capacity over time, hard and soft time windows, shipment to shipment incompatibility, truck to site incompatibility, reverse logistics, combining forward and reverse flows, hubs, cross-docking, and LIFO trucks. Connected to the problem descriptions will we develop input and output formats, most probably in the form of database schemas. These formats disconnect the information aggregation from the development of solution algorithms, and as such both allow parallel development and facilitates integration of these two activities.

Task 3.2 Develop manual planning application

Following the problem description from Task 3.1, we will set out to develop a manual planning application. This application allows us to ensure that all constraints and objectives in the problem descriptions are well-understood and provides an implementation of what decisions are to be taken, i.e., an implementation of what constitutes a solution to the problems. The visualization of both the input data and solutions furthermore supports analysis of the results of the to-be-developed solution algorithms of Task 3.3 and 3.4. The application also supports the crucial interaction between human planner and solution algorithms as discussed by the user interface requirements that are identified in Task 1.2. By connecting the solution algorithms to this planning application we will finally have a prototype of a full-fledged application for integrated transportation planning and execution.

Task 3.3 Develop algorithms for transportation planning

In this task we will set out to develop solution algorithms that solve the transportation planning problem. Difficulty of this task comes from the combination of the required real-life detail, the required instance sizes to be solved, and the required response time. Part of the required real-life detail are time-dependency and stochasticity of the problems. Besides stochastic time-dependent travel times, initial discussions with the LSP project partners confirm that stochasticity in loading times and service times are also relevant in practice. Development and testing of the algorithms will be driven by first focusing on small and simple test instances, each concentrating on a limited set of constraints and objectives. We will next move to small instances where we slowly increase complexity, until we reach full complexity. Next we increase the size of the test instances and again go from simple instances to instances of full complexity. We execute 3-5 of these iterations until we reach instances of full size and full complexity. This simple but effective methodology allows to already test the developed algorithms before realistic instances are available. That is needed as experience shows that getting real-life data is hard and time-consuming. The manual planning application of Task 3.2 supports the testing, facilitating the analysis of the results. The full size of the instances to be solved is defined by the transportation volumes of multiple transportation partners as encountered in a 4C. This may come from actual transportation partners the LSP project partners already have or from combinations of partners deemed interesting to study. The required response times are expected to be at most 8 hours (overnight runs), but in certain circumstances can also be 1 hour or even less.

Task 3.4 Develop algorithms for transportation execution

In this task we will set out to develop solution algorithms that solve the transportation execution problem. Difficulty of this task is different from Task 3.2 as the required real-life detail tends to be higher, the required instance sizes to be solved tend to be smaller, and the required response time tends to be shorter (minutes or even seconds if a real fast response is needed). Still this task is closely related to Task 3.2 as investigation is needed how to best connect transportation planning and execution. That includes studying how detailed and/or robust the transportation planning should be in order to best deal with real-time disturbances in execution. As such this will require combined testing and several development iterations between the two tasks are expected. One of the issues to be solved is answering the basic question of how to test and measure the final transportation execution results. First challenge there is to determine the right KPIs, i.e., determine how we will measure if execution has indeed improved. We plan to start testing by developing simulation software, so that we can test the functioning of the solution algorithms without the need to have a real and real-time connection to the transportation data of the industrial partners. We will aim to as soon as possible use historic data in the simulation tests. Once these tests are passed successfully, we will turn to the real-life testing as described in Task 1.4 of the end-user studies work package.

Planning:

Task 3.1: Month 1-12
Task 3.2: Month 6-12
Task 3.3: Month 13-30
Task 3.4: Month 19-42

Task 3.3 and 3.4 are performed in smaller iterations. In each iteration an algorithm is developed and implemented. While the results of Task 3.3 and 3.4 will be delivered for milestone 2 and milestone 4, along with the integrated system. These tasks stay active during the evaluation to solve small problems that may surface during evaluation.

Work distribution:

Task 3.1: TU/e (task leader), Quintiq, Jan de Rijk, Ewals, Veldhuizen
Task 3.2: TU/e (task leader), Quintiq, Jan de Rijk, Ewals, Veldhuizen
Task 3.3: TU/e (task leader), Quintiq, Jan de Rijk, Ewals, Veldhuizen
Task 3.4: TU/e (task leader), Quintiq, Jan de Rijk, Ewals, Veldhuizen

Jan de Rijk, Ewals and Veldhuizen are only involved to validate the results of the tasks.
The work in this work package will partly be performed by M.Sc. students, who will work on parts of the solution, in particular in T3.3 and T3.4. In total 5 M.Sc. students are planned.

Expected results/deliverables/milestones:

Deliverable D3.1: Formal transportation planning and execution problem descriptions (M12)
Deliverable D3.2: Manual planning application (M12)
Deliverable D3.3: Algorithms for transportation planning (M26)
Deliverable D3.4: Algorithms for transportation execution (M38)

Of the deliverables mentioned above, we expect that at least deliverable 3.1, 3.3 and 3.4 have the potential to lead to one or more scientific publication. We expect to publish parts of these deliverables as papers in scientific journals or conferences.

Due to the involvement of 5 M.Sc. students, 5 Master theses are also deliverables of this work package.

Milestone MS1: Usage Scenarios, Architecture and Early demonstrator (M12)
Milestone MS2: Integrated DAIPEX system, first iteration (M26)
Milestone MS4: Integrated DAIPEX system, second iteration (M38)

Work Package 4: Transportation information integration software

Objectives

- Develop a Complex Event Processing (CEP) engine that can aggregate transportation-related information from data streams.
- Extend CEP technology with the ability to detect and correct inaccurate and incomplete data in a multi-parameter setting.
- Extend CEP technology with the ability to create views on a data stream in such a way that relevant information to a view can be aggregated, but irrelevant information (in particular information that must not be disclosed) cannot be aggregated.

Research approach

Much research has been done on developing the technical infrastructures for Complex Event Processing (CEP), the field of research that focuses on extracting information from high-volume data streams. This work has focused primarily on CEP concepts [8,14], CEP middleware [17,18,19], and lately the integration of events that are generated by RFID readers and tags [15,16]. Our goal is to operationalize this existing research and contribute to it from an application perspective, by achieving the objectives above. In doing so, we aim to develop two important contributions that relate to the last two objectives.

The first contribution is the extension of CEP technology with the ability to detect and correct inaccurate and incomplete data in a multi-parameter setting. While detecting and correcting data in a data stream has been researched [20, 21,22,23], this has been done in a single-parameter setting, in which new events in the data stream are compared to the average that has been computed on the previous events that were observed. We aim to extend this research to a multi-parameter setting, in which other data is used to complement the data in a particular stream. For example, transshipment time can be computed in a single-parameter setting, by computing the average transshipment time of a stream of transshipment events. Outliers can then be detected by comparing the transshipment time of a single event to the average transshipment time. In a multi-parameter setting, we can include data about, for example, the number and type of items that are transshipped. This will help to compute a more accurate transshipment time, especially in case an information about transshipment time is missing or inaccurate for an event, because the transshipment time can be expected to be related to the number and type of items transshipped. To solve multi-parameter data correction problems, we will combine single-parameter approaches with data mining solutions developed by project partners [24,25].

The second contribution is the extension of CEP technology with the ability to create views on a data stream in such a way that relevant information to a view can be aggregated, but irrelevant information cannot be aggregated. The ability to prevent irrelevant information from being aggregated is of particular importance when sharing information between partners of which some information is confidential. Even aggregate information can be sensitive in such situations. For example, when it can be inferred that there are many possibilities to transport items along a particular route, the transportation price on this route will go down. This mechanism will discourage transportation companies to share information on their transportation capacity, because sharing information in this case has the negative side-effect that their margins are challenged. Therefore, we will develop mechanisms for obfuscating aggregated information beyond the view that a partner has on a data stream.

The project addresses the challenges of detecting and correcting data and creating data views, by relating data streams to the transportation processes in which the data will be used. In this way, the business processes can provide additional information that complements the information that is available in the data streams. This information can be used to complete and correct information that is aggregated from the data streams. For example, this information can be used to detect missing events. Missing events can be detected when a process states that a certain event *a* should occur before another event *b*. When the CEP engine then observes *b* but has not observed *a*, it knows that *a* is missing. To solve this problem, we aim to combine process mining techniques that are developed by the project partners [26,27] with a CEP engine. Additional information available in a business process can also be used to define views on the data. In particular, business processes provide information on roles that are authorized to perform certain tasks. That information can be used to define views [9] that correspond to roles and contain only the information that a role needs to perform the tasks for which it is authorized.

The research approach that we will use is a typical data-mining approach. Based on the requirements for information aggregation that are identified in task 1.2, we will collect relevant historical data from the project's industry partners. This historical data can both be used to train the techniques for detection, correction and view creation and to evaluate their effectiveness. Subsequently, we will develop the techniques, based on existing scientific literature, as explained above. Finally, we will evaluate the developed techniques, using the collected historical data. In accordance with the overall project plan, the techniques will be developed in two iterations:

1. in the first development cycle, which focusses on the development of 4C co-planning software, techniques for creating views on data streams based on process models of the transportation process will be developed.
2. in the second development cycle, which focusses on the development of synchromodal planning software in a 4C, techniques for detecting and correcting data in a multi-parameter setting will be developed.

Corresponding to this research approach, the tasks in this work package are defined as follows.

Task 4.1 Literature study in the areas of incorrect data detection, data correction and obfuscation

In line with good research practice, a literature study detailed literature survey will be carried out. Especially in order to determine (single-parameter) techniques for incorrect data detection and correction and to establish to which extent they can be re-used and adapted for use in a multi-parameter context. In addition, related work on data obfuscation will be studied. Accordingly, this task leads to two primary deliverables: D4.1.1 a literature survey towards (single-parameter) techniques for incorrect data detection and correction; and D4.1.2 a study of related work in the area of data obfuscation.

Task 4.2 Develop and deploy initial CEP engine

In this task an initial CEP engine will be selected from the CEP engines that are available in research and practice. This CEP engine will be prepared for deployment towards the development of the early demonstrator (Task 2.2). While existing CEP engines work with separate data aggregation rules, it is the goal of this project to integrate data aggregation functionality with the business processes, because information available through pre-defined business processes can complement information aggregated from data streams. Therefore, the existing CEP engine will be integrated with existing Business Process Management (BPM) software. A deployed initial CEP engine that is integrated with BPM software is the deliverable of this task (D4.2.1).

Task 4.3 Data collection

Based on the requirements that are identified in task 1.2, we identify and collect the data that can be collected to train and evaluate the techniques that are developed in task 4.4 and 4.5. This task will be executed together with both researchers that will work on the development of the techniques in task 4.4 and 4.5 and the practitioners who can help identify useful data and eventually must collect the data from the data centers of the industry partners. The result of this task is a data collection (D4.3.1) for training and evaluation purposes.

Task 4.4 Develop technique for view creation

This task concerns the development and evaluation of a technique for view creation. The technique will primarily be developed for the usage scenario of co-planning in a 4C (also see task 1.2). The three primary challenges that must be overcome to develop the technique are to:

1. develop extensions of existing business process modeling techniques that enable the creation of views on data streams.
2. develop techniques, based on CEP, to aggregate data in a business process.
3. develop techniques to obfuscate data that must not be visible in a view.

The solutions to these challenges will be described in three deliverables, together with prototype software that implements the solutions. Industry partners involved in this task will develop industry-strength counterparts for the prototypes.

Task 4.5 Develop technique for incorrect data detection and data correction

This task concerns the development and evaluation of a multi-parameter technique for incorrect data detection and data correction. The technique will select the two or three most promising single-parameter techniques from the literature survey (D4.1.1) and develop multi-parameter techniques based on them. This will lead to at least two solutions that will be described in deliverables with corresponding prototypes. The precise techniques that will be selected, depend on the outcome of the literature survey (D4.1.1).

Planning:

Task 4.1: Month 1-12
Task 4.2: Month 7-12
Task 4.3: Month 7-18
Task 4.4: Month 13-30
Task 4.5: Month 25-42

While the results of Task 4.4 and 4.5 will be delivered for milestone 2 and milestone 4, along with the integrated system. These tasks stay active during the evaluation to solve small problems that may surface during evaluation.

Work distribution:

Task 4.1: TU/e (task leader), TomTom, EOV
Task 4.2: TU/e (task leader), TomTom, Jan de Rijk, Ewals, Veldhuizen, EOV
Task 4.3: TU/e (task leader), TomTom, Jan de Rijk, Ewals, Veldhuizen, EOV
Task 4.4: TU/e (task leader), TomTom, Jan de Rijk, Ewals, Veldhuizen, EOV
Task 4.5: TU/e (task leader), TomTom, Jan de Rijk, Ewals, Veldhuizen, EOV

Jan de Rijk, Ewals and Veldhuizen are only involved in task 4.2, 4.4 and 4.5 to validate the results of the tasks. They are involved in task 4.3 to assist in the collection of data.
The work in this work package will partly be performed by M.Sc. students, who will work on parts of the solution, in particular in T4.2, 4.4 and 4.5. In total 5 M.Sc. students are planned.

Expected results/deliverables/milestones:

D4.1.1 Literature survey towards techniques for incorrect data detection and correction (M12)
D4.1.2 Related work on data obfuscation techniques (M12)
D4.2.1 Deployed CEP engine with BPM software integration (M12)
D4.3.1 Data collection for training and evaluation (M18)
D4.4.1 Business process modeling extensions for data view creation (M16)
D4.4.2 Techniques for data aggregation in business process data views (M20)

D4.4.3 Techniques for data obfuscation in business process data views (M26)
D4.5.1 Multi-parameter technique for incorrect data detection and correction (1) (M34)
D4.5.2 Multi-parameter technique for incorrect data detection and correction (2) (M38)

Of the deliverables mentioned above, we expect that at least deliverable 4.1.1, 4.4.2, 4.4.3, 4.5.1 and 4.5.2 have the potential to become a scientific publication. We expect to publish parts of these deliverables as papers in scientific journals or conferences.

Due to the involvement of 5 M.Sc. students, 5 Master theses are also deliverables of this work package.

Milestone MS1: Usage Scenarios, Architecture and Early demonstrator (M12)
Milestone MS2: Integrated DAIPEX system, first iteration (M26)
Milestone MS4: Integrated DAIPEX system, second iteration (M38)

Work Package 5: Management

Objectives

- To guarantee the scientific, non-scientific and administrative coordination of all activities of the project
- To ensure the timely realization of all project objectives, milestones and deliverables
- To coordinate the production and delivery of project-reports
- To ensure the achievement of appropriate quality standards
- To ensure that the legal contractual obligations are met in accordance with the consortium agreement

Task 5.1 Project coordination

TU/e is responsible for the project management and assigns a project coordinator for the day-to-day management of the project. The project coordinator is supported by the Project Management Team (PMT) consisting of the work package leader and the Project Board (PB) consisting of a delegate of each partner. The management structure is described in more detail below. The project manager is supported in the administrative and financial tasks by the staff of the Coordinator's Advisory Subsidies and Contracts (ASC) and Dienst Financiële en Economische Zaken (DFEZ).

A Consortium Agreement will be signed at the beginning of the project where among others IPR, exploitation rights, confidentiality, decision and change procedures are described.

The project coordinator will arrange the financial issues (management justification of costs and payment / distribution of money).

Any other management issues (conflict handling, dissemination of information) are handled by the project coordinator.

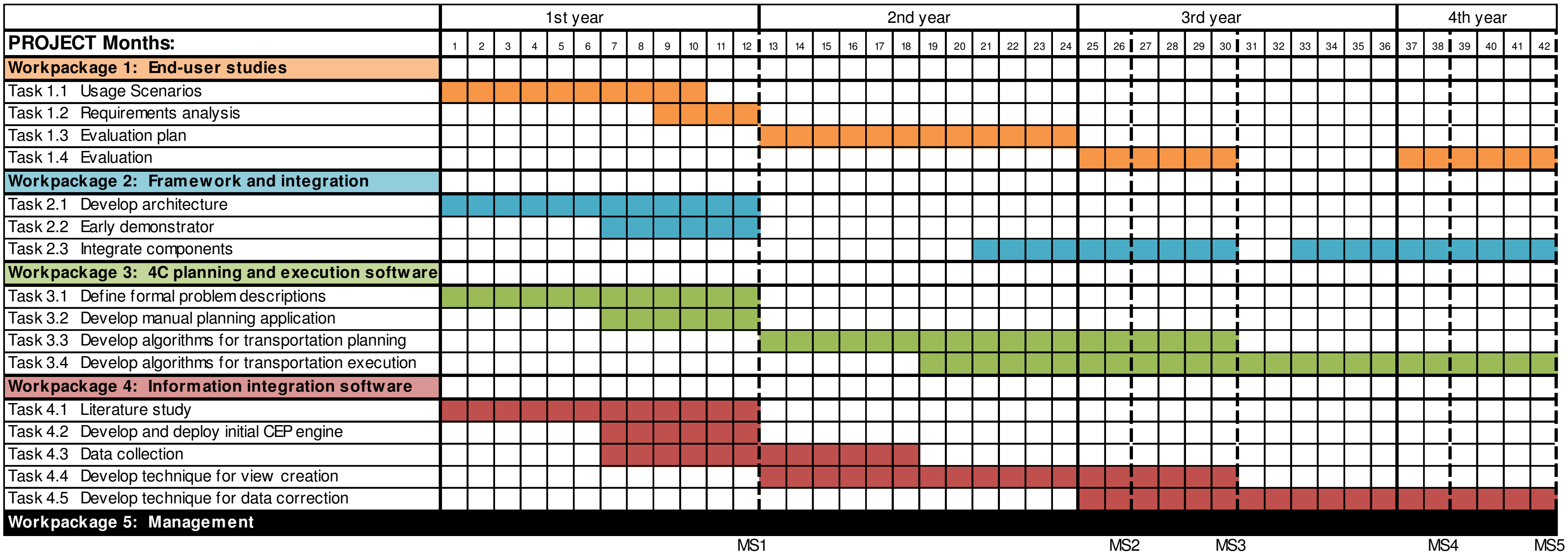
Task 5.2 Internal Communication

The goal of this task is to set up the internal organization of the project. This includes the kick-off meeting and the setup of a collaborative working environment, mailing lists, the

organization and conduction of online and face-to-face consortium meetings and reviews. Part of this task is also the setup and implementation of procedures and policies for the work to be done. The project coordinator will arrange periodic project meetings and prepare the project reviews. The collaborative working environment will be realized as a private part of the project website (project intranet). It will enable all the partners to share reports and deliverables. Furthermore it will include a common project calendar, a section for templates of reports and deliverables and the minutes of all project meeting and events. *Task 5.3 Risk Management* This task will identify and manage risk and opportunity areas, and consider the effects on resources, deadlines and the quality of results. It will mitigate these through mediation or a change of responsibilities. Furthermore, it includes the definition of success criteria and metrics, which will be used to assess the probability of risks during the project. One of the major outputs of this task is the Risk Analysis & Management Plan, which will be one of the main working tools of the project board. *Task 5.4 Reporting* This activity monitors and ensures the success of the project via the provision of adequate reporting of all activities within the project. It consists of the preparation and delivery of periodic and final process and financial reports to the commission. This task also includes obtaining audit certificates from the partners. The project coordinator is responsible for periodic progress reporting to Dinalog. The work package leaders coordinate the activities in the work packages and monitor the progress.
Planning: The management work package is continuous, with a focus on deliverables outlined below.
Work distribution: Task 5.1: TU/e (task leader), all Task 5.2: TU/e (task leader), all Task 5.3: TU/e (task leader), all Task 5.4: TU/e (task leader), all
Expected results/deliverables/milestones: D5.1.1 Consortium Agreement (Month 3) D5.2.1 Kick-off meeting (Month 1) D5.2.2 Collaborative working environment (Month 3) D5.2.3 Project website (Month 6) D5.2.4.1-13 Project meetings 4 times per year (approximate planning: M3, M6, …, M42) D5.3.1 Risk Analysis & Management Plan (Month 6) D5.4.1-7 Half-yearly Management Reports (M6, M12, M18, M24, M30, M36) FR Final Project Report (M42)

Planning

The detailed planning is provided with the work packages above. An overview of the planning is provided in the following Gantt chart.



Consortium and Project Organization

Research Team

Looking at the distribution of work over work packages, specific competences are primarily required in the consortium with respect to knowledge about the transportation domain (WP1), software integration (WP2), transportation planning (WP3), information aggregation (WP4) and project management (WP5). The various project partners have these competences both from a research perspective (TU/e) and a practitioners perspective (other project partners) and will provide their input according to their specific competences as shown in the table below.

Most of the research will be done at Eindhoven University of Technology. Eindhoven University of Technology has a strong track record in solving planning problems [1,5,6,7] and information aggregation problems (in particular using computational intelligence [24,25] and process mining [26,27]). It will also steer the software integration about which it has both strong theoretical knowledge [28] and practical knowledge through participation in research projects with practice that also involved industry partners (such as CROSSWORK and CROSSFLOW). Eindhoven University of Technology will also do the project management, in which it has extensive experience through management tasks in previous research projects such as CROSSWORK, CROSSFLOW and more recently GET Service.

TomTom and Quintiq have extensive experience with planning software and are important players in their respective fields. They will provide demonstration versions of their software and share their practical experience in the context of the project, with respect to software development and software integration. TomTom will also provide transportation data for the information aggregation component.

Jan de Rijk Logistics, Ewals Cargo Care and H. Veldhuizen Transport are transportation companies. Jan de Rijk Logistics and Ewals Cargo Care also operate multi-modally. In particular, they have train and truck lines. These companies will provide the necessary knowledge about the transportation domain and participate in the evaluation of the software. In addition, they will provide transportation data that will be used for information aggregation and transportation planning.

Jan de Rijk and Ernst Opus V also have extensive experience with software development and integration in the transportation domain. They will use that experience to develop some of the core components of the transportation planning and information aggregation software and help with the integration of all components.

Partner's name	**Role and input**	**Specific competence**
Eindhoven University of Technology	- Conduct research - Develop prototype software - Prototype software integration	Transportation Planning Information Aggregation Software integration Project management
TomTom	- Facilitate route planning software development - Provide transportation data	Route Planning Software Information Aggregation Software
Quintiq	- Facilitate transportation planning software development	Transportation Planning Software Software integration

	- Facilitate software integration	
Jan de Rijk Logistics	- Provide domain knowledge - Provide transportation data - Participate in practical evaluation - Facilitate information aggregation software development	Multi-modal transportation
Ewals Cargo Care	- Provide domain knowledge - Provide transportation data - Participate in practical evaluation	Multi-modal transportation
H. Veldhuizen Transport	- Provide domain knowledge - Provide transportation data - Participate in practical evaluation	Transportation
Ernst Opus V	- Facilitate software development - Develop industry-strength software	Information Aggregation Software Transportation Planning Software Software Integration

Project organization

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. The management and decision-making structure are kept as simple as possible with direct communication links between the responsible parties in order to optimize resources for the core activities in the project. The management structure is established to ensure that work is carried out timely and based on strong scientific principles. The proposed management structure ensures the effective administration of the project, careful monitoring of the scientific and technical progress, timely completion of the deliverables, monitoring of the end-user involvement at critical decision points and considering ethical and safety issues. The project management structure, shown in Figure 2, consists of:

- The project coordinator is responsible for the work carried out in the project and monitors the overall project planning, progress and progress reports based on the input of all partners. The project coordinator will assist, when necessary, the work package leaders and makes sure the communication between work packages proceeds smoothly. The coordinator is also the link between the project and Dinalog. The project coordinator role will be fulfilled jointly by Wim Nuijten (TU/e) and Remco Dijkman (TU/e).
- The Project Board (PB) consists of the representatives of all participants and will be chaired by the coordinator. The PB constitutes the decision board of the project. In this capacity, it will be responsible for the final decisions on general project management issues.
- The Coordinator's Advisory Center Subsidies and Contracts (ASC) of the TU/e will handle procedural and financial aspects and coordination of patent policy. The ASC will facilitate in making the Consortium Agreement (CA) as provisioning measure for arrangement of IPR, exploitation rights, confidentiality, decision and change procedures, cooperation after the project end and negotiation with third parties. The ASC is part of

TU/e Innovation Labs. All activities in the field of knowledge valorization are united in the TU/e Innovation Lab. This unit acts as a central point for all questions from the business community. The Project Coordinator's financial department Dienst Financiële en Economische Zaken (DFEZ) will handle the payment distribution, consolidation of cost statements for the project and will give advice on the financial progress of the project.

- The Advisory Board (AB) meets on a regular basis to discuss the progress in the project and the quality of the output. Following the meeting, it provides advice to the project coordinator. All advisory board members perform senior functions in their respective organizations and have experience with (managing) projects. They are not necessarily core members of the project. The chair of the advisory board and advisory board members will be determined at the kick-off meeting.
- The Project Management Team (PMT) consists of the project coordinator and the Work Package Leaders. The PMT supports the integration of the work packages to achieve the desired project results. Across work package coordination and dependencies are managed in the PMT.
- Work Package Leaders coordinate and supervise the work carried out in a work package. Each work package consists of several tasks. To each task the committed participant will be responsible to coordinate and supervise the work and deliverables in that task. Work package leaders will be appointed at the kick-off meeting.

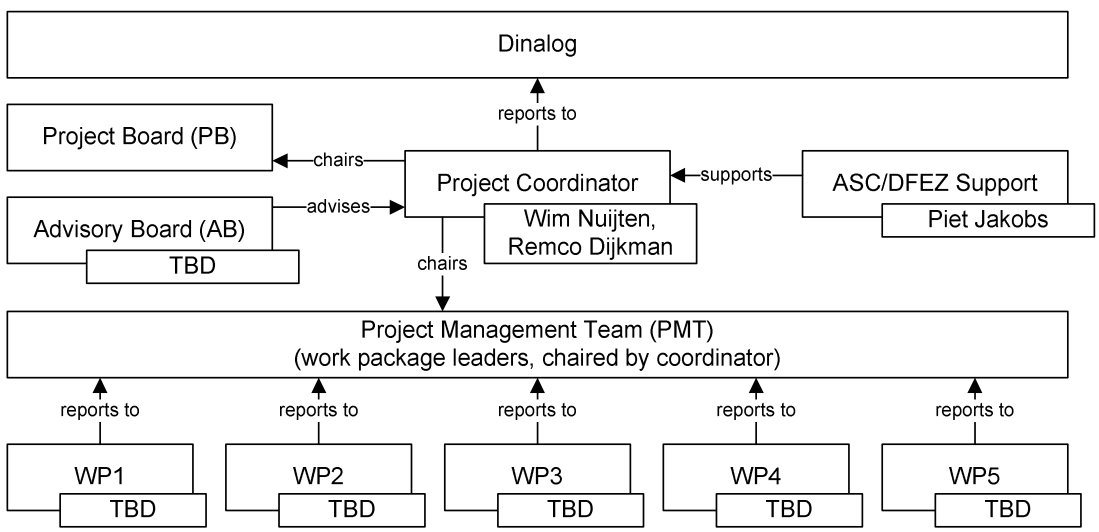


Figure 2. Project management structure.

The consortium will establish a Consortium Agreement (CA), based on the CA proposed by Dinalog, in order to provide a common understanding on:

- contract and additional definitions, duration and purpose, and
- role and responsibilities of the coordinator and each partner.

The consortium agreement will set out the detailed management, coordination and assignment of duties to the partners within the consortium. The final agreement will be drafted by the coordinator. The agreement will be made as a provisioning measure for detailed arrangements pertaining to intellectual property issues (IPR), exploitation rights, confidentiality, decision and change procedures, cooperation after the project end and negotiation of third parties.

The establishment of a fast, reliable and easily accessible communications infrastructure can only be achieved through the intensive use of electronic communications (e.g. shared document management space, email, web based exchanges, virtual project meetings). The communication strategy aims to keep all partners fully informed about the project status at all time. Transparency of the project planning, progress and other issues important to the partners increase the synergy of the cooperation. Interactive project meetings have an important role in the communication strategy. All information such as meeting minutes, visit reports and publications will be communicated to the coordinator. When needed, the coordinator is responsible to channel the information to the adequate parties in the consortium, using the appropriate (electronic) means.

Face to face project meetings and audio meetings (for instance telephone conferences or Skype) are scheduled on a regular basis. At the face to face and audio meetings:

- the work package leaders discuss the status, planning, and progress of the work packages
- the coordinator and the Project management Team (PMT) discuss the cross work package activities, dependencies and overall work package matters concerning technical, scientific, ethical, dissemination, exploitation and management issues,
- the coordinator and the Project Board (PB) provide scientific and strategic direction to the project. They discuss and control the project commitment to the objectives, costs and deadlines.

All partners have the means to communicate using electronic mail, the project-homepage and the project repository.

The communication strategy also aims to effectively communicate with parties outside the consortium, such as other project consortia, other potential users of the technology and standardization committees.

At the start of the project a kick-off meeting is held in Eindhoven and organized by the coordinator. In the kick-off meeting the project work plan, flow of information and the organizational project structure are discussed. Project meetings are held four times a year at different venues with participation from all partners and are organized by one of the partners. Date and location will be decided in the previous meeting. An invitation to the meeting with a proposal to the agenda will be sent out by the coordinator four weeks in advance of the face to face meeting. At each meeting a review of the progress in each work package and plenary discussions among all participants will occur.

Project Board:

- Will meet at face to face at every project meeting and tele-conference frequently.
- At a milestone the PB evaluates the project results and compares them to the project objectives for the milestone. When needed plans are revised. Major changes affecting the project objectives are discussed with Dinalog.
- Extraordinary meetings for the PB may be convened by the coordinator or the majority of the PMT.

Advisory Board:

- Meets at every project meeting
- Has regular tele-conference meetings, such that it has 4-6 meetings per year in total

Project Management Team:

- Meets at every project meeting
- When needed the coordinator organizes a tele-conference meeting.

Work Package members:

- Meet at every project meeting
- When needed tele-conference meetings are organized by the work package leader or member of the work package.

All decisions will be taken at the appropriate level. Day to day decisions concerning a work package at a technical level will be taken by the work package leader. Whenever needed the work package leader will consult the coordinator. The PB will provide a forum for discussing management and major scientific and technical issues. Decisions of the PB are binding for the project. Whenever needed the PB will decide on major issues by a majority vote with the project coordinator having the casting vote. The PB will decide on the work plan and will prepare proposals to Dinalog.

C. Evaluation and Monitoring

Evaluation

A specific project management work package is included in the work package plan, to allow for the implementation of the management procedures. This work package covers all manpower needed for the coordination of the project. Preparation of detailed planning and reporting for tasks in a work package is included in the manpower planning for the respective technical tasks.

The formal half-yearly reporting to Dinalog is coordinated by the project coordinator. After each half-year, all partners report their progress and work package leaders give an overview of the progress in the work packages to the project coordinator. The progress report includes information about the scientific and technical progress, deliverables, compliance with the work plan, encountered problems and person month planned and actually spent. Each partner will also report the annual activities to the coordinator. The project coordinator will prepare the project reports, take care of their distribution and is responsible for a timely reporting to Dinalog. This concerns especially all contractually required technical and management reports as requested by Dinalog.

The work package leader and the task leaders are responsible for timely delivery of the deliverables in their work package and task. Each deliverable will be peer reviewed by two partners. The reviewers are asked by the work package leader and have two weeks to review the deliverable. The deliverable needs to be ready for review at least four weeks before the deadline.

Risks that may impact on this project are as follows:

- Risks arising from the nature of applied research
- Risks related to methods and to the validity of the results
- Risks stemming from multidisciplinary nature of the project partners
- Risks related to balancing objectives of research partners and of other stakeholders

At the beginning of the project, and on the basis of existing risk management practices the team shall produce a detailed Risk Analysis & Management Plan. The plan shall detail the risk management process, in particular putting explicit project procedures in place to track and control risks.

The problem handling methodology of the consortium is primarily based on provisioning. A consortium agreement will be made as a provisioning measure on: the arrangement of IPR, exploitation rights, confidentiality, decision and change-procedures, cooperation after the end of the project, and negotiations with third parties. In case a problem arises, it will be tackled as soon as possible and at the lowest possible level (i.e.: first by the Task Leader, second by the WP-Leader, third by the Project Management Team), meanwhile bringing it to the immediate attention of the Project Coordinator. More details on the procedure will be described in the consortium agreement (CA).

D. Valorization and Implementation Strategy

Valorization and knowledge dissemination

The following valorization activities are planned.

Implementation at project partners: As described in more detail in the ‘implementation’ section below, an important part of the valorization goes directly through our logistics project partners obtaining the described business value. The knowledge of how to obtain similar value for companies outside the project consortium, as well as the operational and consulting knowledge on improved transportation planning and execution projects will be shared through scientific and trade publications. The sounding board group with representatives from all modalities also serves to spread the acquired knowledge. The project will produce software that will be demonstrated to work in practice.

Valorization by marketing generic software and consultancy services at project partners: The generic software that will be developed in the context of the project and the knowledge about how to successfully implement this software to achieve specific benefits will be used to develop generic software solutions and consultancy services. These software solutions and consultancy services will be marketed by our project partners. Thus, the results of the project can be implemented broadly after the project ends.

Valorization through knowledge creation: Through the MSc projects we will educate future experts and as such create human capital. This directly supports the goal of increasing the number of logistics professionals as defined in [11].

Exploring the potential of a 4C startup: While the project primarily aims to develop generic 4C software, it also explores specific 4C scenarios and develops solutions for them. These scenarios are expected to have high potential for creating start-up companies, because they are primarily network organizations and an important part of the business network is already delivered by the project. As these scenarios are developed with the help of MSc students, which often have a high entrepreneurial spirit and already acquire the necessary knowledge to develop the scenarios in the context of this project, we estimate that the potential for a 4C startup after the project is high. We will, therefore, actively explore the potential for such a start-up and, if viable and necessary, acquire the necessary funding (e.g. through an NWO valorization grant).

The following dissemination activities are planned.

Dissemination materials (Flyers and brochures): Two sets of flyers and brochures will be designed and produced. The first set early in the project will disseminate the objectives, concepts, innovations and vision of DAIPEX. The second during the third year of the project will additionally disseminate public results, outcomes and findings. Dissemination materials primarily target both practitioners in transportation and logistics. They will be distributed at conferences and trade fairs that project members attend.

Dissemination events: Dissemination events will be organized for transport and logistics organizations close to the end of the project, during which the prototypes and corresponding project results will be demonstrated. Dissemination events are of specific interest to logistics and transportation service providers. In addition to relations from the project partners, relations from Dinalog and the European Supply Chain Forum (ESCF) will be involved in dissemination activities.

Final summary report: This report is a comprehensive summary of the project's results and conclusions and explains their socioeconomic impact. The publishable report will be formatted for printing as well as for electronic publishing. This report should address a wide audience, including the general public.

Conferences, trade-fairs and trade journals: DAIPEX consortium partners, both from industry and academia, will attend relevant conferences and trade-fairs that target an industry audience. This includes conferences and trade-fairs in the area of transport and logistics and conferences and trade-fairs in the area of enterprise information systems. The conferences, trade-fairs and trade journals listed in the table below are of interest in the two areas and actively read and/or published in by consortium members.

Scientific output: A large number of scientific publications will be published in conferences proceedings, journals and magazines. The fields covered in the project include operations research (specifically: planning) and information systems (specifically: service oriented computing). Scientific output is expected to approximate 3 to 4 journal publications, 3 to 4 conference contributions for both Postdocs. The scientists will also contribute to workshops to be organized.

Implementation

The software that will be developed during the project will be directly implemented at the logistics project partners and will be used to solve the 4C-related usage scenarios that are introduced by these business partners. In this way the expected results and benefits of the project will be directly achieved at the project's logistics partners.

However, the software is intended to be generic. Consequently, it must be possible to implement it at other logistics companies as well after the project has completed. Quintiq, which has as its business to develop transportation planning and execution software will develop software solutions, based on the research that is done in the project, and market these solutions towards their existing clients and also potential new clients that are interested in the 4C premise.

Where the plans of Quintiq to market the solutions that are developed in the project are very concrete, TomTom also has plans, but less concrete. TomTom is primarily interested in the information aggregation aspect of the project and, during the project, will look at opportunities that are offered by the software and business cases that can be made for its valorization.

The developed software is not meant to be off-the-shelf software. Instead, when implementing the software at a new 4C client, knowledge is required about how to configure the software for that particular client. This knowledge will be developed in the context of the project and after the project be available to its consulting partners (specifically Quintiq and Ernst Opus V), which can further exploit the consultancy knowledge.

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Appendix: Curriculum Vitaes of Researchers

Wim Nuijten. Prof.dr.ir. Wim Nuijten is Vice President Optimization Technology at Quintiq and full professor of Intelligent Information Systems at Eindhoven University of Technology (0.2 FTE). His main industrial and scientific interests lie in modeling and solving real-life planning and scheduling problems. Dr. Nuijten is an expert in obtaining scientific results in the area of combinatorial optimization and turning such results into cutting-edge industrial software. Dr. Nuijten received his MSc (cum laude) in 1990 and his PhD in 1994 from the Department of Mathematics and Computing Science of Eindhoven University. After his PhD he went to work for ILOG (from July 2009 IBM ILOG) where he combined doing scientific research, developing industrial software, and using that software in customer projects (including for major companies like SAP and Oracle). He authored 35 conference, journal, and workshop papers, and he is the co-author of the book "Constraint-Based Scheduling", confirming the leading role he has had in the field scheduling problems. He furthermore founded the ILOG Supply Chain Optimization Applications and led the R&D team for 6 years, amongst others developing the products IBM ILOG LogicNet Plus XE (network design), IBM ILOG Transport PowerOps (operational transportation planning), and IBM ILOG Transportation Analyst (tactical transportation planning). In his current role as VP of Optimization Technology at Quintiq he serves a large customer base in the logistics industry (project partners Jan de Rijk and Ewals Cargo Care being examples thereof). The combination of this experience makes that he has an excellent view on what issues logistics companies are faced with in practice.

Key publications:

1. M. SteadiSeifi, N. Dellaert, W. Nuijten, R. Raoufi, and T. van Woensel. Multimodal Freight Transportation Planning: A Literature Review, European Journal of Operational Research, 2013 (to appear).
2. M. SteadieSeifi, N. Dellaert, W. Nuijten, and T. van Woensel. A Mathematical Model for Multimodal Horticultural Transportation Planning, EURO-INFORMS 2013 Joint International Conference, 2013.
3. Development of industrial combinatorial optimization software ILOG Solver, ILOG Scheduler, and ILOG Dispatcher leading to current world-class products ILOG CP Optimizer and ILOG CPLEX Optimization Studio, 1995-2005 and 2011-2012.
4. Development of industrial supply chain applications for the logistics industry IBM ILOG LogicNet Plus XE (network design), IBM ILOG Transport PowerOps (operational transportation planning), and IBM ILOG Transportation Analyst (tactical transportation planning), 2005-2011.
5. Ph. Baptiste, C. Le Pape, and W. Nuijten. Constraint-Based Scheduling: Applying Constraint Programming to Scheduling Problems, 2001.

Wil van der Aalst. Prof.dr.ir. Wil van der Aalst is a full professor of Information Systems at the Technische Universiteit Eindhoven (TU/e). His research interests include workflow management, process mining, Petri nets, business process management, process modeling, and process analysis. Wil van der Aalst has published more than 160 journal papers, 17 books (as author or editor), 300 refereed conference/workshop publications, and 50 book chapters. Many of his papers are highly cited and his ideas have influenced researchers, software developers, and standardization committees working on process support. He has been a co-chair of many conferences including the Business Process Management conference, the International Conference on Cooperative Information Systems, and the IEEE International Conference on Services Computing. He is also editor/member of the editorial board of several journals, including Computing, Distributed and Parallel Databases, Software and Systems Modeling, and Computers in Industry. In 2012, he received the degree of doctor honoris causa from Hasselt University. In 2013, he was appointed as Distinguished University Professor of TU/e. He is also a member of the Royal Holland Society of Sciences and Humanities (Koninklijke Hollandsche Maatschappij der Wetenschappen) and the Academy of Europe (Academia Europaea).

Key publications:

1. W.M.P. van der Aalst, A.J.M.M. Weijters, and L. Maruster. Workflow Mining: Discovering Process Models from Event Logs. IEEE Transactions on Knowledge and Data Engineering, 16(9):1128-1142, 2004.
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5. W.M.P. van der Aalst, and A.H.M. ter Hofstede. YAWL: Yet Another Workflow Language. Information Systems, 30(4):245-275, 2005.

Paul Grefen. Paul Grefen is a full professor in the Department of Industrial Engineering & Innovation Sciences at Eindhoven University of Technology since 2003. He chairs the Information Systems subdepartment since 2006. He received his Ph.D. in 1992 from the University of Twente. From 1992 until early 2003, he held assistant and associate professor positions in the Computer Science Department at the University of Twente. He was a visiting researcher at Stanford University in 1994. He has worked in a number of national and international research projects, both as a researcher and as a manager. In these projects, he has collaborated with a wide range of academic and industrial organizations. His research interests include models and systems for electronic business, architectural design of complex information systems, interorganizational workflow management, high-level transaction management, and support for electronic contracting.

Key publications:

1. R. Eshuis, P. Grefen, 2009, Composing Services into Structured Processes, International Journal of Cooperative Information Systems 18(2): 309-337, World Scientific.
2. P. Grefen et al., 2009a, Dynamic Business Network Process Management in Instant Virtual Enterprises, Computers in Industry 60(2):86-103, Elsevier.
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Uzay Kaymak. Prof. Dr. Uzay Kaymak is full professor in the Information Systems Group at Eindhoven University of Technology. His research is on intelligent decision support systems, data mining and computational modeling methods. Earlier he filled positions at Delft University of Technology, Erasmus University Rotterdam and Salford University. He has been a partner in various EU funded projects. Amongst others, he was the vice-chair for the Industry and Business Applications Committee on Finance, Trade and Services of EUNITE, the European Network of Excellence on Intelligent Technologies for Smart Adaptive Systems (FP5). He was also a node of the European CA on Nature-Inspired Smart Information Systems (NiSIS) and participated in FP6 project "Time-determined ontology based information system for real time stock market analysis" (IST-FP-6-26896-TOWL). Uzay Kaymak has authored over 200 scientific publications in the fields of intelligent systems and computational intelligence. He serves or has served in the editorial board of several journals (a.o. IEEE Transactions on Fuzzy Systems, Fuzzy Sets and Systems, Soft Computing), is member of various technical committees of the IEEE and has served in the PC board of multiple international conferences.

Key publications:

1. M. Setnes, R. Babuška, U. Kaymak, and H. R. van Nauta Lemke. Similarity measures in fuzzy rule base simplification. IEEE Transactions on Systems, Man and Cybernetics, Part B, 28(3):376–386, June 1998.
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Remco Dijkman. Dr.ir. Remco Dijkman is assistant professor in the Information Systems group at Eindhoven University of Technology. His research interests include Business Process Management and Service Oriented Computing. He received his Ph.D. from the University of Twente, where he has held positions as a postdoctoral researcher and as a research assistant. Before working at the University of Twente, he combined work as a research assistant at the Open University of the Netherlands with work as a consultant at Ordina. He has been a visitor of the BPT group at the Hasso Plattner Institute, IBM Zurich Research Lab, the Institute of Information Systems at Humboldt-University Berlin, and the BPM group at Queensland University of Technology. Remco has published over 50 papers in scientific journals, conferences and workshops. His work appeared in Information Systems, Computers in Industry and Transactions on Software Engineering and Methodology. He has worked as a researcher in a number of national and international projects, including the SPICE European project (FP6); and the SHOPPS, NLI, ArCo, and A-MUSE national projects; and he is co-founder of the Dutch BPM Round Table and the European BPM Round Table, both platforms that stimulate collaboration between researchers and practitioners. Currently, Remco is coordinator of the GET Service European project (FP7).

Key publications:

1. Z. Yan, R.M. Dijkman, and P.W.P.J. Grefen. Fast Business Process Similarity Search. Distributed and Parallel Databases 30(2), pp. 105-144, 2012.
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