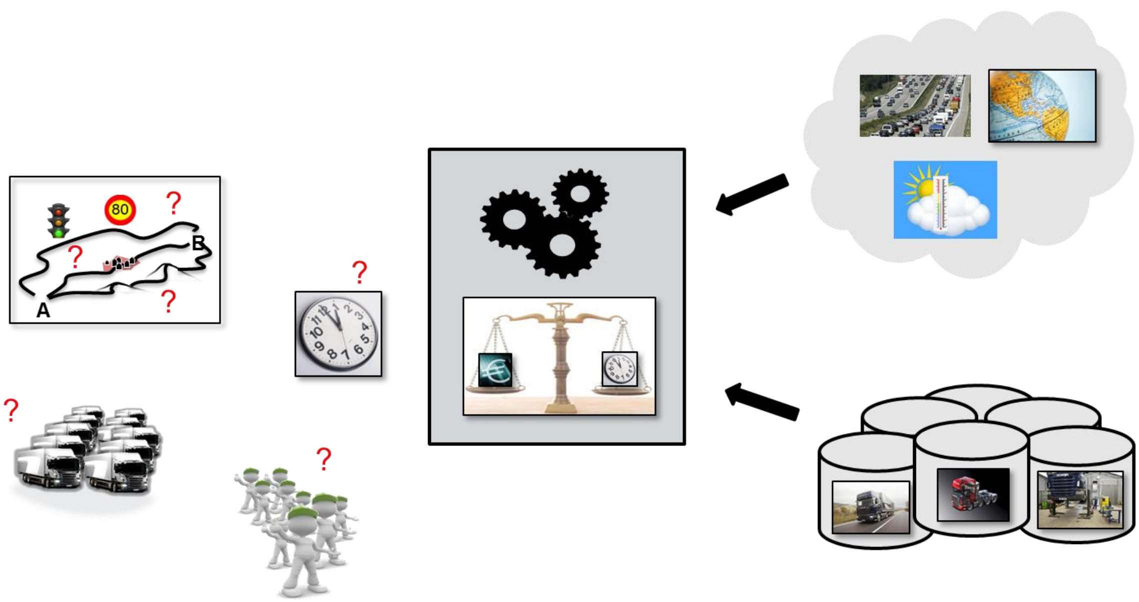
Data-Driven Optimization for Intelligent and Efficient Transports (DOIT)

Public report



Project within FFI - Transporteffektivitet

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Content

1. Summary

Big data analytics offers the possibility to extract valuable information from huge, fast-growing, non-homogenous, and uncertain data volumes. In many business sectors, adaption to this new paradigm can be critical for retaining, or gaining, competitive advantages. This is especially true in the automotive industry and the area of intelligent transport systems (ITS) where accurate and relevant information is crucial for time and cost optimal decisions in systems and services for, e.g., energy optimized vehicle routing and advanced cruise control.

The primary objective of the DoIT project has been to demonstrate the implementation of a data driven approach and how this can to applied within the heavy-duty transport domain. This primary objective has been fulfilled by the development and research into assignment planning optimization and fuel prediction models.

The project has led to increased knowledge of big data and machine learning methods as well as development of data-driven fuel models for optimizing resource utilization and route planning. A web based application demonstrating the solution as they apply to various use cases has also been developed. Publications have been created by SICS in relation to WP3 data analysis and WP4 data driven planning and optimization (T2017:06,T2017:07,T2018:01). Two patent applications have been submitted by Scania

2. Sammanfattning på svenska

Projektets övergripande mål var att utforska och demonstrera hur big data analytics i kombination med optimeringsmetoder kan ge ett förbättrat beslutsstöd vid transportplanering och reducera kostnaderna för tunga vägtransporter.

Projektet har genomförts enligt det upplägg som beskrevs i basrapporten, dvs arbetet har organiserats inom fem arbetspaket med mål och leverabler. Samtliga arbetspaket har haft direkt beroende till en eller flera av de övriga. Utveckling har skett iterativt inom varje paket och parallellt med övriga. Synkronisering mellan arbetspaketeten har skett kontinuerligt. Det huvudsakliga användarfallet optimering av transportplanering har styrt arbete i övriga paket. Krav från utveckling av bränslemodeller har tex styrt krav på förbehandling och konsolidering av data. Vidare har krav från optimeringsmodellen styrt utveckling av tex bränslemodellen.

Projektet har, i linje med förväntningarna, resulterat i bl.a.

- Ökad kunskap om big data, hur det kan tillämpas inom ITS.
- Utveckling av en metod, baserad på kombination av en datadriven bränslemodell och optimeringsmodell, för resursallokering and ruttplanering som minimerar bränsleåtgång och/eller maximerar nyttjandegrad för en flotta av transportfordon över tid.

- En demonstrator med tjänstebaserad systemarkitektur som implementerar ovanstående, som visar hur användarfallet optimal transportplanering kan lösas och vilka kostnadsbesparingar man skulle kunna göra.
- Två stycken patentansökningar från Scania.
- Tre stycken tekniska rapporter från RISE SICS

3. Background

The ongoing and far-reaching developments in the area of data analysis and the unprecedented explosion in availability of data are radically changing the conditions and ramifications for industrial, corporate, and societal activity. This development, having led to the notions of big data and big data analytics, has only recently become possible due to advances in computer, sensor, and communication technologies. Big data is commonly characterized by its extreme dimensions in terms of volume (in terms of Exa- and Peta-bytes), the speed with which it is updated or produced (can exceed disk I/O operations), the heterogeneity of its representation schemes (big data analytics involves analysis of any format), and potential noise and uncertainty in data and data sources. Two key factors of big data analytics are that it makes it possible to extract valuable information from big data, and that the value of the extracted information increases with increasing volumes and rates of the collected data. A third key factor is that big data analytics potentially can unveil otherwise hidden and valuable information about the system being analyzed. Big data and analytics offer therefore significant productivity and efficiency improvements, which in turn can lead to positive impact on resource usage and sustainability of growth.

Big data and analytics, together with connected vehicles, open for a great number of novel systems and services aimed at improving the intelligence and efficiency of road transports. Examples include energy-optimized route planning, intelligent fleet management, data-driven driver support and training, as well as autonomous or semi-autonomous vehicles. Crucial to the efficiency and intelligence of such systems and services is the ability to make, and act on, time and cost optimal decisions. For instance, route planning involves determining the fastest or most energy-efficient route with respect to given circumstances. In driver training, the most energy-economical driving behavior should be determined, and in autonomous or semi-autonomous vehicles, the optimal set speed, or speed profile, is calculated with respect to given constraints (e.g., on arrival time).

Decisions in intelligent transport systems belong to different levels of abstraction, as depicted in Figure 1. The figure shows the hierarchical structure of strategic, tactical, and operational levels for planning and control of heavy-vehicles used for road transports. The strategic level concern transport and route planning. Transport planning refers to the process of assigning a specific transport assignment, described in terms of locations and times for pick-up and delivery as well as specification of the goods to be transported, and a driver to a specific vehicle. Route planning involves deciding which route a vehicle should take when executing its transport assignment. The tactical level concerns road segment planning and inter-vehicle control. Road segment planning involves, for instance, decisions regarding speed and braking behavior with respect to the specific road segments of a chosen route. Inter-vehicle control is particularly important when considering vehicle platooning and involves the decision of the distance to nearest vehicle. The operational level concerns vehicle control. Here, all decisions related to, e.g., engine control reside which comprises for instance throttling through fuel injection and actual operation of the brakes.

Current praxis in decision for ITS is to make trade-offs between usability and accuracy of the models and decision procedures. Such trade-offs often lead to inefficient and suboptimal decisions. One of the main reasons for this is that the models being used are limited in applicability. Models such as driver experience are limited by human working memory and inference capabilities; physical modelling and simulation are limited by high computational complexity and incompleteness. The hierarchical relationship between decisions on the different abstraction layers adds further complexity to the problem where optimal decisions on one level may result in inefficient constraints and directions on another level.

Our working hypothesis has been that a data-driven approach and statistical modelling can provide more adequate models for decision support in ITS than are in use today. Our approach is to use as much data as possible within the limits of the project and to build and run advanced statistical modelling on the collected (and consolidated) data to derive adequate data-driven models for selected areas of ITS decision making.

This project has been focused on research in big data analytics, modelling, and optimization for developing a system that enables intelligent and efficient automated decision for selected problems in ITS where there should be no need for trade-offs between accuracy and efficiency.

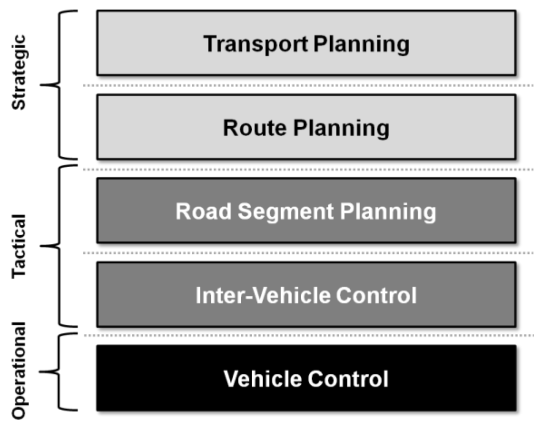

Figure 1 Conceptual hierarchical structure for decisions in ITS.

4. Purpose, research questions and method

The addressed problem is that of developing big data analytics and optimization algorithms and corresponding methods and methodologies for deploying these algorithms in data-driven optimization for automated decision making in heavy-duty vehicle road transportation.

Addressed Research Challenges

Research Challenge 1: Complex Decisions

Despite the existence of viable models, it is not straightforward to set up the optimization problem corresponding to the decision problems described in the introduction. The decisions are generally of very complex and potentially of unknown kinds. First, the decision may have several competing objectives such as minimizing cost while maximizing safety. Second, they may involve variables with unknown interdependencies. Third, the models may in general depend on time and external factors, adding dynamics and uncertainty. Fourth, the decisions are not made in isolation as one decision may affect future decisions. Fifth, decisions are made on several layers; see Figure 1, with different time-scales, dynamics, and conditions of optimality, while affecting a common environment. For instance, the fuel cost of driving a given road segment is tactically determined in the resolution of minutes by factors such as the slope of the road, vehicle weight, and the speed, while the same fuel cost is on the strategic level determined in the resolution of months by the driven distance.

Research Challenge 2: Complex Optimization Problem

Given suitable models for the decisions problem, defining the appropriate notion of optimality and finding the optimal decision are the two optimization challenges. Similar problems are known to be NP-complete and require thus unique solutions for the particular problem at hand. (In other words, there is no effective general solution that can be deployed here.) Note also that the decision may have to consider the optimality of several factors simultaneously, rendering the problem a multi-criteria optimization problem.

Research Challenge 3: Complex Data Models

Deploying big data and analytics in the setting of vehicular road transportation is in itself a challenge. In this kind of analytics, each domain having its unique combination of data sources and modelling requirements, the task of devising the appropriate analysis tools requires qualified research and analysis. This project has dealt with data sources that are distributed and noisy, while also the demands on the model are as diverse as the decisions are complex. The data models support decision on the whole time-scale according to the level of decision, and they need be robust and equally responsive to dynamic changes in the modelled environment.

The methods applied to solve each of the sub-problems addressed in the work packages are described in detail in the three technical reports produced (T2017:06,T2017:07,T2018:01).

Table 1 List of work packages

	Description	***Responsible***
WP0	Project management	Scania
WP1	Vision, requirements, and system architecture	Scania
WP2	Data consolidation and pre-processing	Scania
WP3	Data analysis and predictive modelling	SICS
WP4	Optimization and planning	SICS
WP5	Demonstrators	Scania

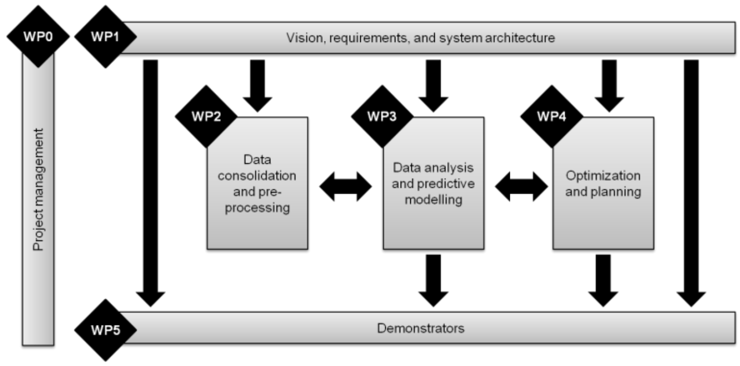

Figure 2 Illustration of project flow.

5. Objective

The overall objective of the project has been to develop data analytics and optimization algorithms and the corresponding methods for deploying these algorithms in data-driven optimization for automated decision making in heavy-duty vehicle road transportation. The project has focused on decisions concerning optimization of time and cost. To achieve the project objective, it was divided into five subordinate objectives:

- Objective 1. Develop algorithms and methods for data-driven modelling of total cost for heavy-duty vehicle road transports.
- Objective 2. Develop algorithms and methods for data-driven modelling of arriving time for heavy-duty vehicle road transports.
- Objective 3. Development of a design methodology for a data-driven model-based system for time and cost optimization of heavy-duty vehicle road transports
- Objective 4. Design, implementation, and demonstration, of a data-driven and model-based automated time and cost optimization system for decisions in heavy-duty vehicle road transports.

The project has been organized in work-packages around a number of use cases involving selected heavy-duty vehicle road transport decisions. Building on the use cases, the project has incrementally developed algorithms and methods according to the five objectives. Objectives 1, 2 and 4 remained unchanged throughout the project, while the lower priority ended up being given to objective 3. A design methodology might be derived by studying how the demonstrator system has been implemented, but the generation of the methodology was only partially completed. The slight change was primarily caused by continuous prioritization of the most valuable work streams at steering group throughout the project.

6. Results and deliverables

The project has been executed as defined in the original base report. This included organizing the project into five work packages with their own set of objectives and deliverables (Table 1, Figure 2). The work packages were then allocated across resources at Scania and SICS. SICS was responsible for driving the research and development of algorithms. While Scania in a project management capacity ensured project milestones and objectives were achieved. Additionally, Scania designed and developed a solution architecture that demonstrated the application of these algorithms created by SICS.

The project has resulted in several contributing factors including;
-increased knowledge of big data and machine learning methods
-development of data-driven fuel models for optimizing resource utilization and route planning as well as minimization of fuel consumption
-a web based application demonstrating the solutions as they apply to various use cases
-publications submitted by SICS in relation to data analysis and data driven planning and optimization (T2017:06,T2017:07,T2018:01)
-two patient applications submitted by Scania

The main objectives of the project have been reached, and the feasibility for commercial deployment of the main ideas expressed in the project application has been proven. The area studied has proven to be of at least as great interest to the project parties as expected.

Some challenges have appeared along the way, out of which two have been particularly noteworthy. The computational complexity of the types of methods studied in this project easily becomes very large. Recent advances in big data technology and methods provides method to handle this, but no fundamental solution. This challenges the initial goal to avoid trade-off between efficiency and accuracy. A main task throughout the project has been to find workable solutions to combat complexity. Also, the subject area of the project (big data) is developing very fast, generating many exciting opportunities for its practitioners. This has affected the project through a rapid turnover of staff. A small core project team was able to successfully handle the relatively short durations of engagement from several other contributors.

The project has contributed to the main FFI goals of reduced environmental impact from road transport and increased international competitiveness for Swedish enterprise. The prospects for reduced environmental impact of road transport have been improved through development a method that can contribute to better routing and scheduling of road transport for an operator. The competitiveness for Scania has been increased through the additional knowledge and experience gained in this area. The project has been conducted within the transport efficiency sub-program. Better route selection and scheduling are important for transport efficiency.

7. Dissemination and publications

7.1 Dissemination

How are the project results planned to be used and disseminated?	Mark with X	Comment
Increase knowledge in the field	X	The project has increased the knowledge and experience of the Scania and RISE SICS staff involved.
Be passed on to other advanced technological development projects	X	New Scania internal projects have been initiated based on the findings.
Be passed on to product development projects	X	The demonstrator developed within the project will serve as inspiration and proof of concept for future commercial service offerings.
Introduced on the market		
Used in investigations / regulatory / licensing / political decisions		

7.2 Publications

The project has resulted in three public technical reports from RISE SICS and two patent applications filed by Scania. A few academic conference publications were originally planned. Due to changes in staffing in the project and subsequent continuous prioritization of the work efforts these were replaced by the public technical reports.

Technical reports
T2017:06 DOIT WP3 Report on Predictive Modeling and Data Insights
T2017:07 DOIT WP4 Report on Planning and Optimization
T2018:01 DOIT WP4 Final Report on Planning and Optimization

The patent applications have the PRV application numbers SE 1651247-7 and SE 1750699-9 respectively.

8. Conclusions and future research

The primary objective of the DoIT project has been to demonstrate the implementation of a data driven approach and how this can to applied within the heavy-duty transport domain. This primary objective has been fulfilled by the development and research into assignment planning optimization and fuel prediction models.

Overall the work has been conducted as planned, and the investigated methods have been shown to have a significant potential for commercialization. In the immediate future the work will be continued internally, but several avenues for further research are also open. A key area that warrants further study is how to combat the challenge of computational complexity when formulating optimization problems within this domain.

9. Participating parties and contact persons

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