Institute of Transport Economics
Norwegian Centre for Transport Research

Summary

Logistics, costs and environment

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The LIMCO-project's objective has been to generate new knowledge and innovations towards smarter logistics management and transport planning, more sustainable business models for Norwegian transport/logistics firms, and efficient ways of utilizing new data sources. Through two capturing solutions for vehicle data and extensive collaboration with participating firms, we performed a range of analyses on four themes: Driving behavior, fuel consumption and environment, vehicle movements and transport costs. The project has yielded methodological progress on converting GPS-data to useful information on trips and loading/unloading stops. Also insights in cost drivers of transport has been improved, through firm-specific analyses of cost and environmental effects of alternative logistics organization and service levels. The project further assessed eco-driving's potential for emission reductions. Insights from the LIMCO-project provide a basis for new logistics solutions, improved understanding of freight transport's complex needs and activities in cities, and for improving important inputs to the National Freight Model.

Background and objectives

Developments within digitalization, logistics software, ERP platforms (Enterprise Resource Management) and sensors on board freight vehicles have increased the amount of data on transport and logistics to new levels. Despite increased data generation, there still exists an untapped potential in terms of utilization of these data for transport planning and optimization, not least because the data are rarely utilized more than superficially and because data are rarely available for research and public planning.

Through the LIMCO project, we established an extensive collaboration with industrial partners and several major transport companies, transport buyers, partner organizations and BI Norwegian Business School to ensure access to data and to perform relevant analyses with scientific relevance. The project's objective has been to generate new knowledge and innovations that can contribute to smarter logistics management and transport planning, more sustainable business models for Norwegian transport and logistics firms, and increased knowledge on utilizing new types of data in efficient ways.

Data capture

Within the project, two dedicated data capture solutions for vehicle data were established. The first solution is based on factory-installed Fleet Management System (FMS)-APIs, while the second is based on a fleet management system using physically installed hardware on-board of the vehicles. For both solutions, data capture consists of two parts: 1) Data for driving behavior and fuel consumption and 2) GPS-data for every vehicle. Data capture started in January 2019 and has increased throughout the project's life. The database includes close to 250 million positions from around 1650 trucks and 200 vans, distributed among 22 transport firms of different sizes and serving different transport segments.

Data

Both data capture solutions generate information on fuel consumption, mileages, operation times, time spent empty running, and driving behavior. Driving behavior is measured through variables such as coasting (the extent to which drivers utilize the vehicle's mass for saving fuel), use of cruise control, over-speeding (the share of time that vehicles are driven at a higher speed than a threshold defined for trucks), braking behavior, etc. The GPS-data contain time-specific location data. Towards the end of the project, one of the data capture solutions also started logging dynamic vehicle weight (total weight) and axle load on the front and back axles of both truck and trailer, alongside GPS-positions - for a small number of vehicles. Further technical vehicle data were added to the dataset for all vehicles.

Time resolution

Frequency of the GPS data varies between the data capture solutions and between vehicle brands, and usually has a frequency of one observation every 1-2 minutes, and up to one observation every 15^{th} minute. In several periods during the project, there were some challenges related to the frequency of GPS observations falling considerably. This illustrates that the reliability of location data from vehicle manufacturers can be an issue, both if the data is relied on as basis for detailed analyses for firms, and when data is used towards the generation of official statistics. In this context, we also performed a number of comparisons with official statistics from Statistics Norway.

Methodological framework

The project's methodological framework can be divided into four elements: Driving behavior and fuel consumption; Environment; Vehicle movements and Transport Costs.

Driving behavior

Fuel consumption is dependent on many factors, most of which are beyond the direct control of the transporter. A factor that can be controlled more directly and relatively quickly, and which also significantly influences fuel consumption, is driving behavior, here defined as the driver's operation of the vehicle while driving. Driving can be divided into three phases: acceleration, cruising and braking. During each of these phases, the vehicle's fuel consumption can be influenced, and the objective of eco-driving is to achieve the highest possible efficiency (movement) with the lowest fuel consumption possible. Eco-driving theory provides a number of insights on concrete improvements on different driving factors that can contribute to lower fuel consumption.

Vehicle movements

An important task in the project has been to develop methodology for converting GPS-location data into trips and stop observations. Building on existing methodology from international, we developed improved methods for conversion that are better suited for urban distribution transport with vans and trucks. We further validated our methodology against a smaller selection of reports to Statistics Norway's survey of trucks. This work has formed the basis for several analyses, both more general ones and firm-specific ones.

Environment

We performed a number of analyses on fuel consumption, noting that this is useful input both in cost models for specific firms and more generic cost modals used towards the National Freight Model for Norway. A challenge in this regard is that data do not yield information on the load that vehicles have on board, and how this influences fuel consumption. The data nevertheless provide a good basis for estimates on how fuel consumption varies with daily mileage, engine size, number of axles, the vehicle's max. allowed gross weight, etc., as averages for different vehicle sizes. We have also looked into differences in fuel consumption depending on where vehicles drive geographically. In all, the data provide information that we previously lacked for Norwegian freight transport.

Vi defined a general rule for calculating CO_2-emissions based on fuel consumption in litre per km. We further compiled values for average fuel consumption, differentiating between transport segments, vehicle categories, engine sizes, number of axles, whether vehicles are equipped with fourwheeldrive, and daily mileage, based on real-world driving in Norway, for trucks included in our data capture. These values can be used by firms as a basis for reporting the environmental footprint of their transports, when fuel consumption is otherwise unknown to them, e.g. because transport services are bought from subcontractors.

Transport costs

We have developed firm-specific cost models based on ownership costs and use patterns for specific trucks. These models can be used for analyses of cost and environmental effects of alternative logistics schemes and service levels provided to customers (see dedicated paragraph). Data needs for such models are large and the quality of input data is crucial for results. Data collected within the project has amongst others yielded information on fuel consumption at a detailed level, and detailed insights into trip- and stop activities and their time use, noting that time use constitutes an important cost driver both through driver wages and capital costs. Our models for transport costs allow many interesting simulation, a few ow which are discussed in later paragraphs.

Alongside the development of firm-specific cost models, we have worked on developing more generic cost models based on the framework developed towards the National Freight Model for Norway (NFM). These are cost models that in addition to a number of road vehicle types also cover several sub-segments for rail, sea and air transport. The framework, combined with GPS and driving behavior parameters from a large number of vehicles, allows improving the models based on real-life vehicle use, time spent on loading and unloading processes, and fuel consumption for different vehicle categories. The objective is to develop a better basis for fuel consumption, annual mileages and time spent in operation for different vehicle types. Further, the material can be used to analyze geographic variation in these factors. Data collected in the project have proven useful for updates of the cost model for several vehicle types, particularly for revising fuel consumption parameters in the latest version of cost models for the NFM.

Insights and results

GPS data were a new source of information for the participating firms. Feedback from these firms indicates that the project's analyses are interesting because they provide insights in cost drivers for transport operations, such as loading-/unloading times at different locations, driving times and trip statistics at route level.

In order for cost models to provide the best possible representation of transport costs, it is important that data on cost drivers build on a representative factual basis. An advantage of truck data is that they provide objective information on the amount of transport and that data are collected automatically as long as there is an active subscription through fleet management system (including GPS data). This is to say that inputs to cost models can easily be updated to newer periods, without a need for new surveys or large scale data collection. The data and cost models could further become central elements in initiatives towards continuous improvements of transport. Data can make visible areas with a potential for improvement, help design (corrective) measures, as well as allow for calculating cost effects of measures.

Environmental effects of improved driving behavior

Within the project, a mini-pilot was carried out to assess cost and environmental effects of improved driving behavior. Longer-term effects were studied and results published through a scientific article in Energy Research & Social Science (Pinchasik et al., 2021). Our results indicate that a course in eco-driving, combined with active follow-ups and non-monetary rewards can yield more effective driving behavior among truck drivers. We find significant and considerable fuel savings, which we estimate to 5.2-9%. In line with previous studies, we find large variations between drivers and indications of a learning curve: effects occur quickly and increase before reaching a peak. Contrary to previous findings, we find that effects do not significantly fall or disappear over time. This indicates that following up an eco-driving course with additional measures might contribute to strengthening its effect.

Of four factors that represent eco-driving strategies, we find that improvements in motor and gear handling yield the largest fuel savings potential, followed by improvements in speed and traffic management (use of cruise control and avoiding over-speeding). Consistent with previous studies, we find that fuel consumption is significantly lower at higher temperatures and significantly higher with more precipitation. Some observations from our study further suggest that it takes relatively little for minor but non-negligible fuel savings to be achieved.

Vehicle movements

Following development of a method for tracking vehicle movements, we performed a number of analyses on stops for loading and unloading in urban areas, stops for mandatory resting and parking of vehicles, and for identifying locations of stops. We further worked on linking trips and routes and with analyses of route choice, while data were also used in firm-specific analyses.

Overall, we find that loading and unloading stops over the day are distributed rather similarly for different transport segments, but also identify some differences. For example, a larger share of construction transports has loading/unloading activities taking place in the morning and mid-day than other transport segments. For transport of construction materials and foodstuff, the share of stops in the late afternoon and evening is relatively large compared to other transport segments. For urban areas we performed analyses of where trucks and vans stop for loading and unloading, and how much time such activities take in respectively central, and less central city areas. This provides insights both for firms carrying out these transports and for planning purposes, and we find noteworthy differences between Norway's largest cities.

In addition to loading and unloading times, GPS data are also a source of information on where and when drivers take their mandatory breaks. Information on time and location for such stops can provide important insights, e.g. for planning of where to establish fast charging infrastructure for electric trucks. Results show that resting stops take place throughout the day with a peak between 1 PM and 4 PM, and that the distribution of resting stops is similar between different days of the week, with some exceptions. Further, we find a clear pattern showing that most trucks are parked for the night some time during the afternoon or evening, with a peak between 7 PM and 9 PM. This pattern is similar for most weekdays.

For participating firms, we further carried out analyses for identifying locations for truck stops. This has, amongst others, provided input in firm-specific analyses.

Weight data

As previously mentioned, sensor data on weight load first became available towards the end of the project period and only for a small sample of vehicles. Analyses that we performed indicate that there are currently still considerable data challenges, and that even given data with good quality, it will be necessary to perform several challenging steps and to develop ways to systemize utilization of these data and for distinguishing between data of good or poor quality.

Examples of applications

Our work has provided important insights into the balance between service level (e.g. how often cargo is picked up, when, and in what volumes) and costs. The analyses also provide insight into 'fixed' and 'variable' costs for various transport activities and revealed that pick-ups of return cargo often take place even when volumes are below the minimum that is specified. One applied example includes analyses of the importance of return cargo volumes from both a cost and CO_2-emissions perspective. An interesting finding is that minimum pick-up volumes required to make pick-ups worthwhile economically, differ from minimum volumes required from an environmental perspective.

Moreover, we have carried out methodological development in order to provide a better basis for identifying bottlenecks in logistics operations. Insights in such bottlenecks help firms define more targeted improvement strategies. Through a user case, we have further linked GPS data to order data (deliveries). Even though data quality issues make it challenging to perform such linkages for individual shipments, these efforts illustrate areas with potential for improvement, measures that should be performed, and how cost effects of such measures can be measured.

In the project we have looked at how GPS data can be processed and operationalized in order to yield information on freight activities in urban areas, at a more detailed level than traffic counts can provide, and more frequently and cost-effectively than traditional observational studies. For example, there is a need for more detailed information on delivery and pick-up activities in urban areas. Examples include where these activities take place, how much time loading and unloading operations take, and how user patterns can change over time as a consequence of changes in e.g. infrastructure, traffic situations, transport demand or policy measures.

To develop good insight into city logistics, there is also a need for information on the types and volumes of freight that transports carry. GPS data do not provide such information. This means that other sources of information are required, but these are either not available today, or linking them to GPS data is challenging.

Regarding the potential for integrating vehicle data with data from ERP platforms (Enterprise Resource Planning), we have assessed today's possibilities and challenges, as well as expectations for the future. Today, such integration faces considerable barriers. This is also concluded from our attempt to link shipment data and vehicle data based on information on time and location. We developed methodology for identifying trips that with a high level of probability match vehicle and shipment data. However, this methodology should be improved to exclude trips with very few stops, while we are also in need of methodology that is more accurate for such trips.

Needs for more detailed data

Transport models that Norwegian transport authorities use for planning entail high demands to input data. Because increases in freight transport and specifically in city logistics require improvements in transport models, also this increases the need for more detailed information. In December 2020, TØI published a literature study on the State of the art for future transport models (Mjøsund, Pinchasik and Hovi, 2021). This review showed that development of freight transport models internationally to a large degree is driven by access to data on commodity flows and vehicle movements.

A review of freight transport data available today shows that the main data challenges are lacking consistency across transport modes, that survey studies entail a high reporting burden, and that reporting is simplified (and thereby less detailed) for trips (the survey for light goods vehicles) and for distribution rounds (survey of trucks). It can further take a long time between data collection and publication. Moreover, reports on a time dimension largely lack from survey studies, as this would considerably increase their reporting burden.

We find that the large amount of data that is generated with each transport assignment yields large possibilities for future data collection. This applies both to data that could be used towards transport modelling, but also with regard to reducing the burden of reporting to Statistics Norway. Concrete examples include data from ERP systems (freight flows), systems used by firms (freight flows and linkages to vehicles based on planned/actual activity), electronic freight documents (freight flows with linkage to vehicle), transport management systems (TMS) (freight flows with tracking throughout the supply chain) and smart tachographs (GPS data and information on whether a driver stops for loading/unloading, to take a break, or other activities).

Need for future work

The main challenge with electronic data capture is the ownership of data. Transport firms carry freight for other firms, making it important that data are anonymized before they are reported. This issue is particularly important when data are captured from TMS suppliers. Such TMS data could be a very effective alternative to current practice for Statistics Norway's commodity flow survey. Another (methodological) challenge is related to the quantification of the total population, when the total population is unknown.

GPS data provide a rich source of information, but have to be processed to yield information on information on freight activities. Through the project, we also experienced that there are challenges related to access to data (transporters need to have both active subscriptions and be willing to share data). Use of GPS data may further give rise to privacy concerns. However, we conclude that these concerns are more of a hypothetical nature than that they constitute a real problem, as it will only be possible to track drivers who own a vehicle themselves and who regularly park their vehicle on their own property. Within the current project, no attempts were made to investigate the degree to which this is the case.

Digital tachographs could potentially make it possible to gain access to GPS data, independently of whether truck owners have active subscriptions through the supplier of their fleet management systems. It is also a possibility that owners/managers of data (e.g. the Norwegian Road Transport Authority) can link GPS data with technical vehicle data from the vehicle registry, and to industries by using the firm's registration number. This would allow distinguishing between transport firms and firms carrying out their own transports.