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Efficiency Gains from Using Telematics Data Analysis on Large-scale Electric Postal Fleets

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Abstract

Kyburz Switzerland AG designs, produces, and services the light delivery vehicles which postal services around the world use to replace loud and noxious gasoline scooters for door-to-door mail delivery. With many thousands of vehicles in the field, and hundreds of millions of kilometers traveled, Kyburz Fleet Management is integral to saving costs and making good design decisions about its vehicles. In this paper we describe important operational insights which were generated using a set of tools which we developed. When developing new analytic features, our design philosophy emphasizes delivering clear, easily understandable results whose generation is automated where possible. Integral to our work is the concept of respect for the privacy and autonomy of the drivers and other agents in our data collection systems.

Keywords: telematics, deployment, fleet, ICT (information and communication technology), energy consumption

1 Introduction

The trend towards connected cars is accelerating with many apparent opportunities but also many hidden challenges. Some consultants place the future of the broadly defined connected vehicle business in the high billions annually, but highlight that uncertainty and new entrants will likely challenge traditional services provided by incumbents [1]. Much of this business is driven by the needs of companies to improve efficiency, but there are also interesting emerging trends related to individuals examining their own behaviour through the lenses of data analytics which are worth paying attention to [2]. Analyzing telematics and other data has been the subject of targeted research suggesting that flexibility and ease of use are important, but this relatively young area is still evolving [3]. Privacy and anonymous data analysis has been the focus of previous academic research [4]. In particular, there have been several notable efforts directed at understanding how drivers can be motivated to drive more economically [5], although some studies have shown the impacts to be marginal [6]. Relatively limited work has been performed on using accelerometer data to anonymously monitor fleet driver activity for safety and warranty purposes, but some studies have been performed [7].

1.1 Electrifying postal fleets

The large fleets run by postal services spend a substantial fraction of their operating budget on energy and service costs. To reduce these costs dramatically, the Swiss post decided to exchange their 50cc gasoline powered delivery scooters with electric alternatives such as the Kyburz DXP shown in Figure 1. The gasoline powered versions consume 8.4 L/100km on average in real world conditions [8], whereas the DXP uses around 0.8 L/100km equivalent [9] - a factor of 10 less energy consumed in electric operation. Due to their severe usage in postal service, the gasoline powered scooters were custom built and expensive relative to normal consumer variants, and still required replacement 2.3 times as often as the electric DXP.

(a) Piaggio Liberty post delivery scooter

(b) Kyburz DXP post delivery scooter

Figure 1: Since 2009 the Swiss Postal Service has been replacing its fleet of gasoline powered delivery vehicles (Subfigure 1a) with various electric alternatives such as the Kyburz DXP (Subfigure 1b) and since 2017 the fleet is entirely electric

2 Kyburz Fleet Management

In Kyburz Switzerland's Fleet Management team we are driven by the goal to provide easy to operationalize insights regularly and without sacrificing the privacy of any agent in the system. We understand that there is a substantial hesitation from both employees as well as employers to install data collection technologies. In the three use-cases described in this paper, we will illustrate with specific examples how we protect individual privacy while still generating useful data.

The backbone of our telematics offering is formed by two flavours of on-board unit (OBU) which we procure from third-party suppliers but which contain individual firmware which we designed to serve the needs of our customers. The OBU shown in Figure 2 may be installed in heavy-duty vehicles such as 10T trucks, all the way to light-duty vehicles such as the DXP with simple variations in firmware which are typically performed remotely. The OBU has interfaces to the vehicles CAN bus, and can be used to remotely diagnose problems, record vehicle consumption, and even download tachometer data. Via a Bluetooth link, the OBU is capable of transferring road tax data securely to the responsible authorities. The focus of this paper is the electrification of postal fleets and how telematic data analysis plays an important role in improving both operational and energy efficiency. To date, the Kyburz Fleet Management systems have been installed in over 750 vehicles worldwide, such as those shown in New Zealand in Figure 3.

Figure 2: The Kyburz Fleet Management telematics system, with integrated GSM,GPS,CAN, and motion modules

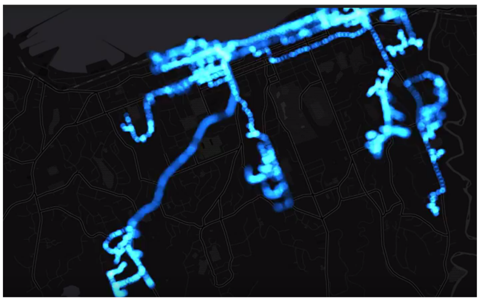
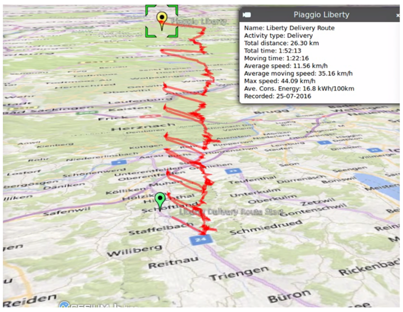


Figure 3: Kyburz DXP vehicles tracked during morning deliveries in New Zealand

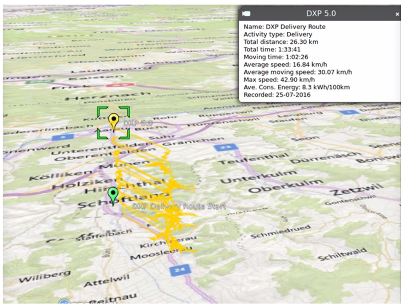
An important tool which Kyburz Fleet Manage-



Piaggio Liberty

Name: Liberty Delivery Route
Activity type: Delivery
Total distance: 26.30 km
Total time: 1:52:13
Moving time: 1:22:16
Average speed: 11.56 km/h
Average moving speed: 35.16 km/h
Max speed: 44.09 km/h
Ave. Cons. Energy: 16.8 kWh/100km
Recorded: 25-07-2016

(a) Piaggio Liberty post delivery scooter route CO2



DXP 5.0

Name: DXP Delivery Route
Activity type: Delivery
Total distance: 26.30 km
Total time: 1:33:41
Moving time: 1:02:26
Average speed: 16.84 km/h
Average moving speed: 30.07 km/h
Max speed: 42.90 km/h
Ave. Cons. Energy: 8.3 kWh/100km
Recorded: 25-07-2016

(b) Kyburz DXP post delivery scooter route CO2

Figure 4: The Kyburz DXP reduces the CO_2 emissions of postal delivery typically by a factor of 4. This spatial-temporal CO2 emission representation generated using the fleet panels allows operators to see exactly which parts of the routes are most emissions intensive.

ment offers to postal service providers is the ability to examine the energy and emissions profiles of their vehicles with extremely fine granularity. Figure 4 shows the CO_2 emitted by the DXP and the Liberty scooter over the same route on a map, with the vertical Z axis displaying their relative carbon emissions. This allows operators to not only make objective comparisons of the vehicles, but also to optimize routes which allow particular vehicles to serve areas best suited to their strengths, for example electric vehicles in mountainous regions and diesel vehicles for long-haul trips.

2.1 Adaptive Management Console

Traditionally fleet management has been performed in a compartmentalized manner, with individual needs driving the development of specific solutions [10]. This leads to complex and costly systems which are difficult to service and scale on one hand, but on the other hand can be efficient and effective in serving their functions. The Kyburz Management console is made up of two main components. A traditional map-based vehicle localization and management portal, and an adaptive management console. The map-based console shown in Figure 5 allows users to locate their fleet in real time, determine the status of each vehicle, and identify possible safety or efficiency concerns manually.

We have also developed an innovative 'Adaptive Management Console'. This platform automatically processes millions of vehicle records and presents the resulting information in a way in which it may be easily interpreted by busy managers. One view from the fleet management portal which we have developed is shown in Figure 6. There is an active approach to protect individual identities in the dataset, going as far as to not associate a vehicle with a driver, for example, which provides the manager with the option to identify the root of problems without associating them too quickly with operator errors. This de-personalization not only avoids bias but protects privacy. The portal is implemented in such a way that content automatically updates to stay relevant, and open-ended user queries are supported in a way which differs substantially from traditional fleet management portals. For example, a user can query 'How many vehicles are currently driving in Canton Zürich?' and receive a simple textual answer instead of having to manually navigate through the map-based menus while applying filters by hand.

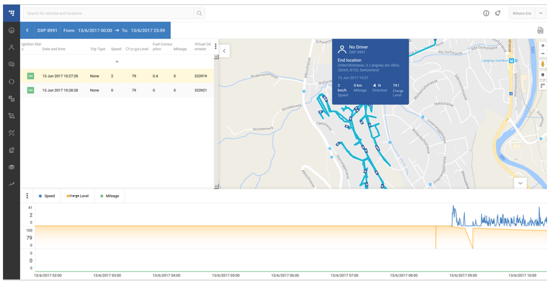


Figure 5: Screenshot of the map-based data management console

Figure 6: Screenshot of the highly adaptive data management console

2.2 Shock Detection

Postal fleet operators are often interested in ensuring that their vehicles are used according to the manufacturers specifications in order to ensure the safety of their drivers and the warranty of their vehicles. To assist fleet operators, the Kyburz Fleet Management OBU is capable of detecting rough driving on DXP vehicles using integrated accelerometer sensors. A peak indicating a hard shock incurred through impact or irregular driving over obstacles is shown in Figure 7 where the amplitude and duration are calculated using thresholds which were defined over standard test conditions.

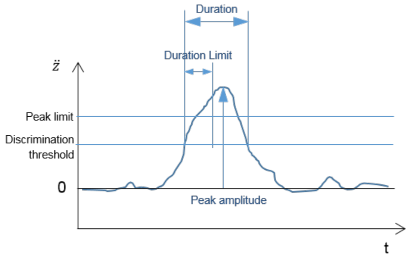


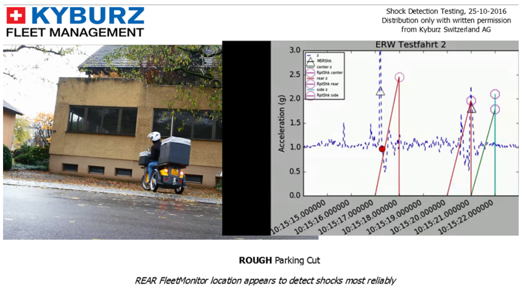
Figure 7: Shock intensity is measured by an OBU mounted above the rear axle and quantified be amplitude and duration

In order to validate the OBU's acceleration sensor which samples at a relatively low rate of 50Hz, an datalogger with a precise accelerometer capable of over-sampling at 1kHz when shocks are detected was used as a benchmark. The results of the test are shown in Figure 8 where it is clear that the OBU detects the same shock events as the high-frequency accelerometer. To further validate our approach, four scenarios were defined which are representative of common occurrences during postal delivery operations:

- Parallel mounting/dismounting of a curbstone at 15 km/hr (rough) or 6 km/hr (gentle)
- Perpendicular mounting/dismounting of a curbstone at 15 km/hr (rough) or 6 km/hr (gentle)
- Driving over a double-sided speed bump at 35 km/hr (rough) or 15 km/hr (gentle)
- Entering/leaving a cut road parking spot at 25 km/hr (rough) or 10 km/hr (gentle)

In order to calibrate the devices for shock detection on the DXP we performed a large battery of 120 tests. After processing the data against ground truth recorded by the test drivers, the accelerometer peak and duration thresholds of 22.5 m/s^2 and 15ms respectively were chosen as shown in Figure 9a. These values are seen to minimize false positive and negatives and reduce the noise in the data passed to the fleet manager. It was observed that the load carried by a DXP had a substantial impact on the acceleration characteristics of the vehicle while it traversed the various obstacles.

In order to account for this in the parameterization, a series of tests at different load levels were performed, and the results are summarized in Figure 9b for the optimal parameters of 22.5/15 where the false negative fraction is the lowest, and now false positives were recorded. These parameters were chosen under the assumption that it would be more detrimental to identify a shock where none occurred then to miss actual shocks. The results of validating the shock detection methodology are shown in Figure 10.


KYBURZ
FLEET MANAGEMENT

Shock Detection Testing, 25-10-2016
Distribution only with written permission
from Kyburz Switzerland AG

ROUGH Parking Cut

REAR FleetMonitor location appears to detect shocks most reliably

Figure 8: Extensive empirical testing demonstrated that the OBU matched high frequency accelerometer data well in identifying shocks

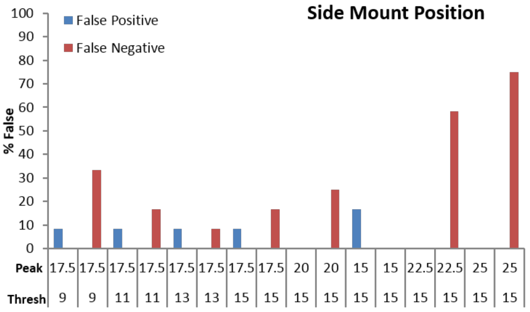
This data is presented to managers with an emphasis on over-performing drivers and locations on postal routes which are prone to inducing shocks which can be detrimental to vehicle longevity. An example of how operational data is gleaned from the shock position data is shown in Figure 11 where an outlier is clearly visible and can be matched to a route to enable route optimization and general training for all drivers. An aggregate set of shocks for a particular postal location are displayed to a manager together with the insight that most shocks occur in a particular location at a particular speed. Statistics have been performed linking the number of shocks recorded for a vehicle with its service record, and these results will be presented in the context of predictive maintenance tools for fleet managers in future work.

2.3 EcoDriving

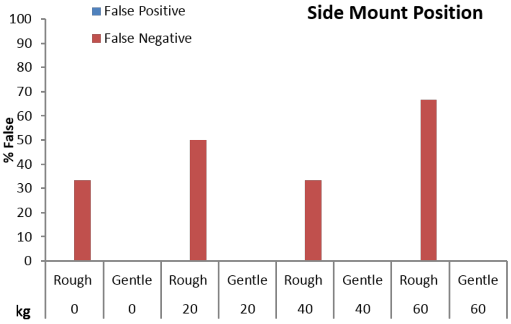
The challenge of motivating drivers to drive economically is multifaceted and well studied but yet solutions remain elusive. The approach we have developed is to provide an attractive interface seen in Figure 12 which presents a playful comparison of an individual driver's performance versus that of an anonymous group. Timely notifications are provided which highlight places where drivers could improve their efficiency in certain parts of a delivery route.

For drivers who are interested in a more detailed summary of how their EcoDrive scores were arrived at, the tool also presents the six factors which make up the score as seen in Figure 13, and also explained in detail in Equations 1 to 6.

The historical performance for drivers can be seen in Figure 14 so that improvements can be observed and celebrated. In the design of this interface the implementation team was careful to adhere to the principles of positive reinforcement where trends in the right direction are emphasized instead of punishments applied for drivers whose scores are slipping. The Ecodriving scores were calculated using Equations 1 to 6 for the parameters



(a) Peak and duration threshold parameters were evaluated to minimize Type I and Type II error



(b) The impact of weight was considered since the vehicles change weight dramatically during their delivery route

Figure 9: A detection peak of 22.5 m/s^2 and 15ms threshold was selected as shown in Subfigure 9a, and it was noted that with these values the sensitivity to weigh changes was minimized as shown in Subfigure 9b

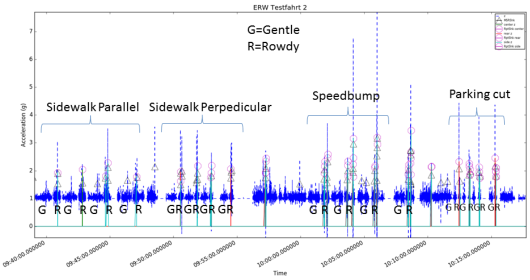


Figure 10: Four scenarios common to postal route driving were identified, and the shock identification algorithm was calibrated

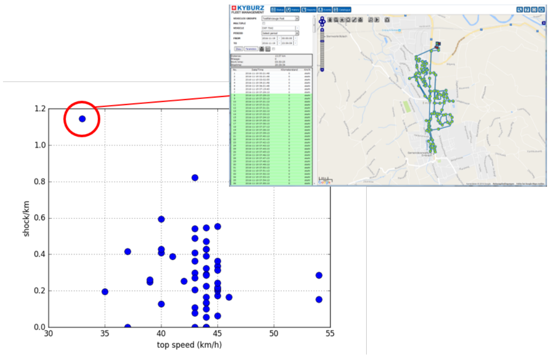
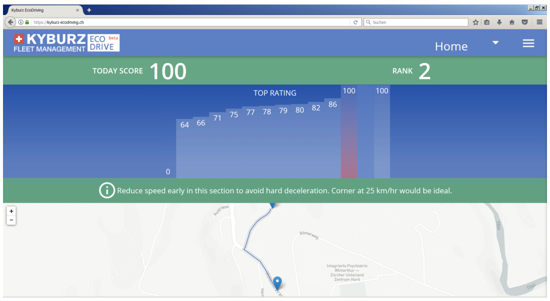


Figure 11: Using real data from 10 vehicles over a period of 60 days, outliers helped to identify postal routes which were more susceptible to shocks when normalizing for driven distance and time



Reduce speed early in this section to avoid hard deceleration. Corner at 25 km/hr would be ideal.

Figure 12: The EcoDriving interface is effective in nudging drivers towards better behaviour using anonymous ranking and comparison to his or her peers

1. E1: Idling Time where T_i is the time spent idling
2. E2: Time at high RPM where P_r is the percent time when RPM is in the red, and T_d is the total driving time
3. E3: Max RPM where θ_m is an empirical RPM threshold and RPM_m is the maximum

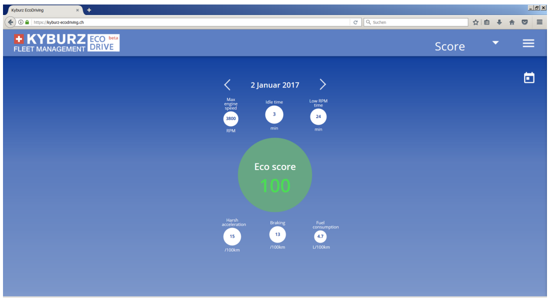


Figure 13: A detailed summary of the factors influencing a drivers' daily Ecodrive score are provided

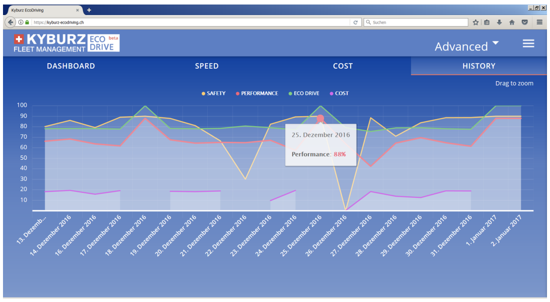


Figure 14: To motivate drivers, their improvement over time is available in a variety of representations

recorded RPM

4. E4: Harsh acceleration where R_h is the rate of harsh acceleration events per 100km
5. E5: Fuel consumption where θ_f is an empirical fuel consumption threshold and R_f is the rate of fuel consumption in L/100km
6. E6: Braking rate where θ_b is an empirical braking threshold and R_b is the rate of braking events per 100km

$$E_1 = 1 - \frac{T_i}{\max\limits_{T_i \in S}(S)} \tag{1}$$

$$E_2 = \frac{(1 - P_r) \cdot T_d}{\max\limits_{P_r, T_d \in S}(S)} \tag{2}$$

$$E_3 = \frac{(\theta_m - RPM_m)}{\max\limits_{\theta_m, RPM_m \in S}(S)} \tag{3}$$

$$E_4 = 1 - \frac{R_h}{\max\limits_{R_h \in S}(S)} \tag{4}$$

$$E_5 = \frac{(\theta_f - R_f)}{\max\limits_{\theta_f, R_f \in S}(S)} \tag{5}$$

$$E_6 = \frac{(\theta_b - R_b)}{\max\limits_{\theta_b, R_b \in S}(S)} \tag{6}$$

$$\tag{7}$$

$$\begin{aligned} ECO = (&w_1 \cdot E_1 + w_2 \cdot E_2 + w_3 \cdot E_3 \\ &+ w_4 \cdot E_4 + w_5 \cdot E_5 \qquad (8) \\ &+ w_6 \cdot E_6) \cdot \sigma_e + \omega_e \end{aligned}$$

A battery of 12 tests was performed with three different test drivers, each driving the same route with the same vehicle. Two replicates of an ecological driving style and an aggressive driving style were performed by each driver. The resulting comparison of self-evaluated driving style versus Ecodrive score shown in Figure 15 shows that there is near-perfect agreement between how the driver thought that they were driving and how the system evaluated their driving style. In 11/12 cases the system correctly matched the drivers' self-identified score.

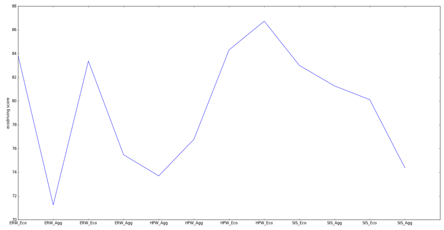


Figure 15: The EcoDrive app's performance was evaluated and found to correlate closely to driver experience

3 Summary

In this paper we have demonstrated how the trade-off between obtaining valuable insights from fleet data versus the stress which collecting and using this data places on relationships between employers and employees may be balanced using three case studies. Our systems and interfaces have all been designed to either collect and present aggregated and anonymous data to managers (e.g. Adaptive Management Console and Shock Detection) or to provide feedback directly to drivers (e.g. Ecodrive Interface). The developments which we describe have been fully implemented and tested, and have resulted in real savings without spending excessive time in understanding the data or paying high prices in personal capital.

Acknowledgments

The authors would like to acknowledge the contributions of their colleagues in the Service Department of Kyburz Switzerland, in particular Abel Olaechea and Andreas Zopfi, without whose strong support this work would not have been possible. They would also like to thank Flurin Vicentini for his early work on the Kyburz Fleet Management systems laid the foundations for what we present here.

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Simon Isenschmid started his career with an apprenticeship in electronics followed by further education in the fields of economics, IT, accountancy, marketing and management. After a several years as a hardware and software quality assurance Engineer he joined KYBURZ Switzerland where he works as a fleet management Engineer.

Hans-Peter Wepfer worked after his graduation as an electrical engineer in the development of industrial electronics and software. With the change to a Swiss SME he took the lead in the R+D of telematics systems. By completing a degree in Executive MBA he was in charge for the business division and for the sales of telematics systems. For the past two years Hanspeter Wepfer is responsible for the development and sales of Fleet Management Systems at KYBURZ Switzerland AG.

Martin Kyburz is an electrical engineer. After several years in Swiss industry, he founded Kyburz Switzerland AG a Swiss company which has focused on the development and production of electric three and four wheel vehicles for more than 20 years. In recent times he is passionate about finding solutions for the needs and troubles of postal delivery and other logistic companies, including fleet management issues.