Big Data for Mobility Tracking Knowledge Extraction in Urban Areas

D6.6 Experiments Monitoring Report, Learning conclusions

Document Summary Information

Grant Agreement No	780754	**Acronym**	TRACK & KNOW
Full Title	Big Data for Mobility Tracking Knowledge Extraction in Urban Areas		
Start Date	01/01/2018	**Duration**	36 months
Project URL	https://www.trackandknow.eu		
Deliverable	D6.6 Experiments Monitoring Report, Learning conclusions		
Work Package	WP6 Pilots and Validation		
Contractual due date	31/12/2020	**Actual submission date**	31/12/2020
Nature	Report	**Dissemination Level**	PU
Lead Beneficiary	ILS		
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This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement No 780754.

Revision history (including peer reviewing & quality control)

Version	Issue Date	% Complete[1]	Changes	Contributor(s)
V0.1	06/11/2020	5%	Initial Deliverable Structure, Chapter 3	Ibad Kureshi (ILS)
V0.2	18/12/2020	25%	Fleet contributions	Athanasios Koumparos (ZEL)
V0.3	20/12/2020	50%	Chapters 1, 2, 5.1	Ibad Kureshi (ILS)
V0.4	22/12/2020	70%	Health contributions	Toni Staykova (CEL)
V0.6	24/12/2020	85%	Insurance contributions	Leonardo Longhi (SIS)
V0.7	27/12/2020	90%	Chapter 6	Ibad Kureshi (ILS)
V0.9	29/12/2020	100%	Chapters 4 refinement	Athanasios Koumparos (ZEL), Leonardo Longhi (SIS)
V1.0	30/12/2020	100%	Peer Review	Jenny Rainbird (ILS)

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[1] According to TRACK&KNOW's Quality Assurance Process:
Due Date - 6 Weeks: Peer Review
Due Date – 2 Weeks: Quality Manager Review (INTRASOFT)
Due Date - 2 Days: Sent to Inlecom for Submission to the EC after addressing all comments by Quality Manage and Peer Reviewers

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Glossary of terms and abbreviations used

Abbreviation / Term	Description
API	Application Programmable Interface
APP	Application
BDA	Big Data Analytics
BDP	Big Data Processing
CCG	Clinical Commissioning Group
CER	Complex Event Recognition
CP	Car Pooling

CRM	Customer Relationship Management
DB	Database
DVLA	Driver and Vehicle Licensing Agency
EC	European Commission
ETSC	European Transport Safety Council
EV	Electric Vehicle
FMUC	Fleet Management Use Case
GA	Grant Agreement / Grant Amendment
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
GP	General Practitioner
GPI	Genuine Progress Indicator
GPS	Global Positioning System
GUI	Graphical User Interface
ICE	Internal Combustion Engine
IMN	Individual Mobility Network
KPI	Key Performance Indicator
LCA	Life Cycle Analysis
ML	Machine Learning
NHS	National Health Service
OSA	Obstructive Sleep Apnoea
PII	Personally Identifiable Information
POI	Point(s) of Interest
RDBMS	Relational Database Management System
SH	Stakeholders
TRL	Technology Readiness Level
UAT	User Acceptance Testing
UC	Use Case
UI	User Interface
WHO	World Health Organisation

1 Introduction

This deliverable is the final report under Task 6.1 Experiments Planning. Monitoring and Learning Conclusions. This report builds on D6.1 (initial setup of the pilots including problem statements, expected business benefits and description of the use cases), and provides a report on activities under taken and final learning conclusions. For each of the Track&Know use cases, this report provides the following information:

- Summary of implementation and challenges
- Performance assessment
- Lessons learnt
- Achievement of Key Performance Indicators
- Value propositions

This report consolidates lessons the learned from the implementation of the project pilots, incorporating validation and analysis of results for pilot measurements and provides this information in a public report.

1.1 Mapping TRACK&KNOW Outputs

Purpose of this section, is to map TRACK&KNOW's Grant Agreement commitments, both within the formal Deliverable and Task description, against the project's respective outputs and work performed.

Table 1-1 Adherence to TRACK&KNOW's GA Deliverable & Tasks Descriptions

TRACK&KNOW GA Component Title	TRACK&KNOW GA Component Outline	Respective Document Chapter(s)	Justification
DELIVERABLE			
D6.6 Experiments Monitoring Report, Learning conclusions	This report will consolidate lessons learned from the implementation of the project pilots	Chapter 3-6	Covered by tables and discussion to capture lessons learnt from each pilot uniformly
	Incorporating validation and analysis of results for pilot measurements.	Chapter 4, 5	General Pilot KPI's and Domain specific KPI's listed and attainment presented.
TASKS			
Task 6.1 Experiments Planning. Monitoring and Learning Conclusions	Aiming to monitor progress in the pilots and document learning conclusions that will feed back into the next development iteration.	Chapter 2	A summary of the progress over the project of all the pilot experiments is provided here.
	a) **Implementation plan** validation for each use case: Document and Validate detailed use case **timeline**, including intermediate **milestones**; Acquire Key Stakeholders buy-in on the	n/a	This subtask related to D6.1

	implementation plan; Identify **key resources** roles, competences and require engagement; Recruitment of testers from the relevant activity domains		
	b) **Use cases scope update & KPIs definition**: Modelling and planning of the experiments will be carried out. Material prepared for Knowledge elicitation, performed with workshops and questionnaires. The key sub-deliverables for each of the pilot use cases to be tested are: A SMART Problem Statement, A clear test plan including a set of measures and performance indicators (along with their calculation algorithm and linked with the relevant data elements), specific test roles with allocated owners and timeline linked with the delivery of the respective deliverables.	n/a	This subtask related to D6.1
	c) **Experiments Monitoring**: Technical Progress Monitoring: On-going monitoring and logging of the use case's Technical Implementation (installations and progress of implementation for infrastructure and applications), Business Goals Monitoring: Perform user surveys and collect data for indicators, on 6- month basis, following the initial implementation plan establishment. Validate results, with business users, and collect feedback. Scenarios, Processes, Roles descriptions.	Chapter 2, 5	Report on activities and methodology undertaken to deliver the pilots.
	d) **Validation and Reporting**: validation and analysis of results for pilot measurements, learning refinements	Chapter 4, 6	General Pilot KPI's and Domain specific KPI's listed and attainment presented.

1.2 Deliverable Overview and Report Structure

This deliverable is the result of three years of regular meetings (in person and telco), between technical and non-technical partners, along with regular experimentation, analysis, and discussions throughout the project. The purpose of this deliverable is to provide a description of the working environment and decisions that led to the final implementation of the three pilot. This report also synthesises the attainment of KPI's across the pilots.

This report is structured in the following way:

- Chapter 1: Introduction (this section), outlining the report and how it relates to the project as a whole
- Chapter 2: A summary of how the different pilots were carried out, including interactions with other work packages and the Track&Know platform. Each pilot is described in its own subsection.
- Chapter 3: Presents a template used to uniformly gather outcomes of each of the business questions across each of the pilots.
- Chapter 4: Each subsection uses the template presented in Chapter 3 to present their assessment of results and lessons learnt.
- Chapter 5: Presents an assessment of attainment of Pilot specific KPI's, learnings for each pilot and how they will be used to improve the pilot businesses, and lessons learnt from operating these pilots.
- Chapter 6: Conclusions.

2 Pilot Implementation Summary

2.1 WP6 Implementation Activities

Work package 6 Use Cases & Domain Validation commenced in M3 (March 2018) and has run till the end (Dec 2020/M36) of the Track&Know project. During this time the three pilots worked together to shape the technical development of the Track&Know platform and toolboxes. Identifying commonalities between each pilot and determining the best pipeline of tools was a collaborative process carried out during the first reporting period.

This work was carried out under WP1 activities to create the Track&Know Knowledge Observatory and identify the Corporate Big Data requirements (D1.1 and D1.2 respectively). Accordingly, fortnightly teleconference meetings were held for the first 18 months that covered both pilot specific research and requirement analysis. Pilot specific teleconferences were also held on a monthly basis. In period 2 of the project each pilot had a fortnightly call. Typically, at project plenaries (held quarterly) each pilot received half a day to show case achievements, discuss results and plan activities for the upcoming quarter.

Each pilot was supported by one to two technical and a bridging (semi-technical) partner. The technical partners focused on creating the bespoke specific technical advancements over the general toolboxes. These were typically data pre- and post-processing pipelines that were necessary to achieve the specific final needs of each pilot. The bridging partners played a vital role of translating business specific goals into terms that the technical partners could codify and vice versa, along with running the technical aspects of the pilots. The remaining partners focused on the core development of the technical components that comprise the Track&Know platform.

Each pilot gave intermediate presentations to respective stakeholders (internal and external) when appropriate. While initially a regular half-yearly survey questionnaire was planned, the realities of Plan-do-check-act cycles meant that intermediate developments were incremental or refinements. Each pilot however presented its results at multiple touchpoints to gain valuable feedback. These are reported in D6.2, D6.3, and D6.4 (version 2.0) respectively.

The three pilots agreed on two parallel thematic streams of work that would both benefit their businesses and utilise the toolboxes of Track&Know. The toolboxes are not ‘solutions looking for a problem’ but are in fact the only method available, based on the data available, to answer the business questions of the three pilots. Each pilot also made use of one to two algorithms available in each of the 4 toolboxes and utilised the Track&Know platform. The two thematic streams were:

- **Service Optimisation:** Optimising the standard business practices to make them more cost effective, and environmentally responsible.
- **Driver Behaviour Profiling:** Detecting impaired or abnormal driving behaviour that could not be explained by road and weather conditions.

To ensure that each pilot did not just lock into one approach, based on the sub-team supporting it, a speed dating session was held. For this session, each pilot partner provided their business questions the data they had available, and the current KPI’s, and then each suitor (the technical partners) moved table to table to see where their specialisation could propel the raw data forward. This session helped all the pilots identify the missing pieces of enrichment or analysis required to meet their objectives.

2.2 Auto Insurance and Innovative Mobility Services

Originally, envisioned as the first pilot (Pilot 1), due to a partner change in M3 of the project, this pilot swapped time scales with pilot 3. The original partner (Partner 8-OCTO) had made data available to the consortium via the replacement partner SIS. However, to retain control of the dataset only a small sample was made available to be copied to partner machines for testing and to be placed on the Track&Know platform.

The main bulk of the dataset remained on site at partner SIS with an exposed API which would only accept connections from the Track&Know platform. The platform in turn could access the whole dataset and compute it on the cloud while not retaining any data for security and compliance reasons. Users who were registered as working on the SIS pilot could activate the Kafka topic which would establish the link. Once the topic has not been used for a set period of time the topic expires severing the link. This formed the basis of the 'online' analysis.

For the 'offline' analysis, partner SIS had the technical competencies to run the codes in-house on their own systems. Additionally, partner CNR had on-site access to the data. Bilateral agreements were signed to ensure the safety of the dataset between those technical partners explicitly working on the SIS pilot.

Due to this already disconnected form of development, work was impacted during the COVID-19 pandemic as partner SIS was not able to attend any plenaries in 2020. The quarterly plenaries served the purpose of effectively synchronising and planning research activities.

Pilot 1 did achieve all its technical goals by M31 of the project and used the holiday period to complete the documentation process, submitting on time at the end of M33.

2.3 Healthcare Service

The original partner for the Pilot 2 withdrew during the Grant Agreement process and were replaced by another arm of the UK's National Health Service. The Royal Papworth Hospitals (PAP) joined the project with their Obstructive Sleep Apnoea (OSA) service being the pilot drivers. While the original pilot concerned Emergency Healthcare (previous partner was an ambulance operator), PAP was concerned with service optimisation based on mobility analytics as they had a large 'customer' base that was geographically disparate. The particular changes to this pilot have been documented in deliverable reports D1.2, D6.1, and the deviations chapter in D6.3.

The consortium believed that medical propensity was critical to providing context against the medical data and therefore partner PAP worked on transcribing several clinical notes into a tabular form. In total, 42,000+ patient appointment records were made available to the consortium. Of these, complete OSA related medical data for 10,000 patients (about 1 year of appointments) was also provided. During the validation phase of the project a further 9 months of appointment and medical data was provided.

Bilateral agreements and data transfer protocols were setup to ensure this sensitive PII data was treated securely. Kafka topics on the cluster would expire, encrypting the at rest data. Unlike Pilot 1, the platform administrator would need to manually decrypt the data and repopulate the topic.

Based on the rural nature of the original PAP hospital the decision to assume all patients used automotive transport was taken. This is because for much of the catchment area public transport would require patients to commute to a train station, followed by a train in London and then back out to either Cambridge or Huntingdon, followed by a 25–40-minute bus journey. While patients living in the Cambridge-Huntingdon corridor could use public transport the bulk of the patients resided outside feasible (<1hr commute or <3 changes) links. With this assumption, Google and Openrouteservice API's were used to reconstruct the patients probable routes. This translated the appointment data to mimic GPS traces.

For the second stream of work – driver behaviour profiling, the appointment data was not feasible, therefore partners ZEL worked on an APP that PAP could put in the field to capture real GPS traces. This leveraged the existing ZEL data pipeline through to the Track&Know platform.

As pilot 2 needed to put its app in the field (with patients and shift workers) this pilot suffered the most due to COVID-19. Non-essential medical procedures were suspended therefore access to the patient pool was lost. The Ethics process, required to give the App to shift worker, was delayed as initially all non COVID-19 related research was suspended. With permission from the Project Officer, the submission of D6.3 was delayed by 2 months to M35. The hope was that the situation would improve to the point where a limited trial (fewer patients and shift workers) could be held. However, in the end a very limited trial (using a handful of shift workers) was carried out. The trials did provide valuable insights and have showed opportunities for future research.

2.4 Fleet Management

At the start of the project, Pilot 3 was most mature in terms of data availability and clarity of business use cases. Therefore, due to the changes of partners in both Pilot 1 and 2, Pilot 3 was brought forwards as the first pilot to be delivered. This change in order was carried out as part of the project grant amendment.

Partner ZEL's customer base was large and included many different types of vehicles with differing business needs. Data from each vehicle would reach ZEL's operational platform and then an API would create copies of the data on the Track&Know platform. Due to the size of the fleet available Track&Know could not ingest the complete dataset or acquire all vehicles data in real-time. Initially, ZEL would allow the platform to collect historic data during operational off-peak hours to preserve their bandwidth and computing power. In terms of collecting live data the costs of using public clouds to collect and retain such large amounts of data was prohibitive. The project was at risk of incurring USD 1,250 per day in costs. This, based on the project budget, would have given only 12 days of operation. Therefore, historic data was limited to the specified KPI target, and the platform was able to connect for live data at any point. This would be restricted to messages from up to 10,000 vehicles.

Partners were given a significant subset of the data for "desktop research and development" work, allowing for early prototyping before the platform was fully ready.

During the course of the project partner ZEL upgraded their own existing platform and infrastructure to match the Track&Know platform – thus lending credibility to its reusability, scalability, and reliability. As part of the pilot implementation ZEL data was initially processed by the BDP toolbox on the Track&Know platform and eventually those tools were partially incorporated into ZEL's own business pipeline.

By the time the impacts of COVID-19 were being felt the technical work on Pilot 3 was complete and the consortium was in the process of documenting the work. There was therefore no disruption in work on this pilot. As the project continued after the submission of the Pilot 3 report, partner ZEL was able to perform more experiments, simulations and analysis. This led to a second submission of D6.4, which is available as V2.0.

3 Final Evaluation and Assessment Template

The Pilots' performance assessment, lessons learned & value propositions collection, involved an iterative process carried out throughout the life of the project, to not only collate operational measurements, learning outcomes and conclusions, but also drive refinements following the submission of the respective deliverables.

The following four tables are the bases by which each Pilot has documented higher level gains from the use of tools in Track&Know. Each table cell on the right provides a detailed description of the requested input.

Table 3-1 Pilot X - Objectives & Operational Measurements

Objective # / UC#	1 / UC1
Description	Describe your organization's objective either from the business perspective, or the technical one (or both).
TRACK&KNOW Applied Concepts / Innovations	Outline which TRACK&KNOW Concepts / Innovations were applied, and how they supported in the achievement of the envisioned objective
Measurement Method	State the KPIs (exact metrics) used and the methodologies applied to measure the KPI associated with the success or otherwise of the pilot objectives.
Initial (Baseline) KPI	Specify the exact metrics utilized to measure the success of the particular objective and their respective values before the application of TRACK&KNOW
Mid-term TRACK&KNOW KPI	KPIs value, at mid-term Evaluation Report (if available), following the application of TRACK&KNOW Technologies
Final TRACK&KNOW KPI*	**Final KPIs value**, following the application mid-term proposed refinements, further experimentation and more wider scale utilisation of TRACK&KNOW Technologies
Economic and Societal impact Update	**Final Analysis of TRACK&KNOW-driven Economic/Societal impact** (including investment), including elaboration of the overall reasoning and the assumptions made. If simulation-based results have been applied, briefly describe the simulation method, results and relationship to the real world.
Qualitative Business Impact Evaluation Update	Outline **final** feedback from key players (roles). Further elaborate on the Qualitative business impact recognized by each of the stakeholders and role (do consider elements such a "user satisfaction", "image", "reputation", "social responsibility", "end-customer perspective", etc. Also, log specific "user" comments/remarks)

Instructions to respondent: Update the Final KPI measurements, the Economic Impact as well as the Qualitative Business Impact. In the occasion that there has been a change on the measurement method, or a new KPI has been added, the table has to be updated accordingly.

(*) *In case Mid-term TRACK&KNOW KPI(s) have been revised in the final year, do add one more row, to describe KPIs value(s) at project closure. If not, keep only one row, named "TRACK&KNOW KPIs".*

Table 3-2 Pilot X – Learning Outcomes & Conclusions

Best Practice Description	**Describe** (or update) **the approach** followed to accomplish the envisioned goals, along with the related indicators. Do clarify, **why the applied approach can be considered as a best practice**.
Reference Objective(s)	Identify (the number of) the objective(s) (from the above table) for which the Best Practice has been identified
TRACK&KNOW Solution	Outline key TRACK&KNOW components (strategies, applications, infrastructure) that have been employed to achieve the specific objective(s)

Post-TRACK&KNOW Enhancement	(where applicable) Identify a **high-level action plan,** supported by your organization to ensure wider deployment of TRACK&KNOW Solutions that would further enhance the positive impact of the particular practice in your organization, following project completion.
Investment	Outline any investment required to implement the enhancement
Expected Impact	Outline what is the expected impact(s)

Instructions to respondent: During this period, you consider that a particular approach/technique applied in the Pilot, led to outstanding performance, and can be considered a Best Practice, please fill in the respective fields. Do repeat, the table above where more than one Best Practices have been identified.

Table 3-3 Pilot-X - Proposed Refinements

Refinement Description	Assuming that one of the Pilot's envisioned objective has not yet achieved, or specific KPIs are below set targets, outline the objective referencing to the related indicators and explain the potential reason(s) for failing to achieve it.
Improvement	Outline/**Update** the improvement framework, describing the revised goals and improvement actions (e.g. in the areas of deployment, or integration), and how is this framework expected to lead to the desired results. Where applicable outline which parts of the TRACK&KNOW solution need to evolve or become more effective, to support reaching the desired KPI values.
Post-TRACK&KNOW Action Plan	Identify a **high-level action plan** supported by your organization, purposed to accelerate or enhance TRACK&KNOW findings/offering, post-project implementation.

Instructions to respondent: The above table should be filled only if you consider that the performance of the particular Objective was not satisfactory, and corrective actions are necessary, or further solutions enhancements are required. Do repeat, the table above where more than one Refinements have been identified.

Table 3-4 Pilot X – Conclusions & Economic Benefit Analysis

Conclusions	**Update mid-term conclusions** with **key learning outcomes and recommendations/ conclusions** at project closure. Do link where applicable with your **final Economic Benefit Analysis**. Identify potential **guidelines**, for either users/solution-providers engaged in construction/participation of similar information sharing ecosystems.
Conclusion 1	
Conclusion 2	

4 Performance Assessment & Lessons Learned

This section of the report provides a summary of the lessons learned in each pilot and completed Final Evaluation and Assessment tables as shown in section 3.

4.1 Auto Insurance and Innovative Mobility Services

As shared in D8.5, there is room for increasing the effectiveness in TRL by tuning the timing of the data agreement and the condition of use of the data. The sooner the conditions of use of the data value and the data value chain itself are agreed on by all the involved parties, the sooner the scientific activities can take place.

From a research point of view the lessons learned are mainly related to the way of addressing the pilot KPIs.

The first one is that it is possible to forecast the global insurance risk of certain urban areas, mostly related to car accidents, as a sum of individual insurance risks. Then it is possible to reduce the global risk by decreasing the individual ones and reward virtuous drivers without exposing insurance companies to any losses, but instead giving both the drivers and the insurance companies the chance to gain profits from responsible driving behaviours.

Therefore, economic profit can be achieved as well as the decrease of reported car crashes. Additionally, the positive feedback given by the ML model could be subsequently spent as a qualified recommendation in Car Pooling services and improve the urban virtuous circle involving also drivers' private car-pooling services.

It is also possible to quantify, in the same geographic areas, how many drivers will have significant profits in switching from their ICE vehicle to an EV or to join mixed mobility transportation services (not owning a vehicle anymore) without experiencing any time loss. That results in a direct CO_2 emissions decrease, proportionate to the saved ICE trips and in an indirect profit, by saving fuel, maintenance, government taxation, etc. when switching to EV, and additionally by not having an insurance or vehicle mortgage costs when joining the sharable mobility services together with the public transportation instead of owning a private car.

The performance tests showed that it is possible to profile 500 vehicles for an entire year at the sustainable cost of less than 4 Euros in a partial B2B scalable market model (reference in D7.2).

The solution presented in the Pilot1 does not need to track drivers with a sampling rate of one position per second and it also works for mixed sampling rates, that means that also works for different TSPs in compliance with the data schema.

The solution is also deployable in each existing environment which uses Kafka for data streaming and it doesn't depend on the kind of noSQL DB used for the data warehouse.

Table 4-1 Pilot 1 - Objectives & Operational Measurements

Objective # / UC#	1 / UC1
Description	SIS has developed a Pilot to investigate if it is possible to deploy a sustainable tool of driving habits profiling which is able to give important results in urban and metropolitan private mobility in the three considered business areas such as : (UC1) Insurance Risk mitigation, (UC2) Electric Vehicle business leveraging and (UC3) Car Pooling services leveraging. This has been conducted in a partial B2B selling mode, to pursue a shorter time to market, high market penetration and quick scalability for its SHs software environment.
TRACK&KNOW Applied Concepts / Innovations	The Offline analysis, already described in several deliverables, has been taken as the best pursuing method to obtain valuable results from mixed sampling rate datasets coming from several TSPs or several customers. This ensures a wide range of applications for Pilot 1 and an increasing number of business markets to join (ref. D7.2). The BDP toolbox with its Individual Mobility Network extracts the measures for the KPIs final evaluation, but it also benefits from the real-time pipeline methods, running through Kafka, of

	the BDA toolbox, especially the Trip Enhancer. The Map matching building block, the visualization layer and the NoDa System have also been considered as valuable output themselves, both as a standalone and in conjunction with the Pilot and the T&K platform. For further details please refer to D8.5 cpt. 4.1
Measurement Method	For this section please refer to D6.2 cpt. 2.5.1, 2.5.2, 2.5.3
Initial (Baseline) KPI	There aren't any custom related proprietary algorithms in the Pilot1. The only tools used are the toolboxes that are part of the Track&Know project. All the requirements and the goals achieved in the Pilot are customer independent. The only constraint was about raw data elaboration and data visualization, due to previous property agreements between SIS and its stakeholders. The mitigation strategy has been described in D6.2 cpt 2.3.1 as a pre requirement of the whole Pilot 1.
Mid-term TRACK&KNOW KPI	Pilot specific KPIs values were not ready at the time of the mid-term review due to a shift of the research activities in order to agree with the data condition of use for the Pilot1. For further information please refer to D8.5 cpt. 4
Final TRACK&KNOW KPI*	For this section, in addition to what was already shown in D6.2 cpt. 2.5.1, 2.5.2 and in 2.5.3 please refer to D6.2 cpt. 2.3.1, 2.3.2, and 2.3.3 section : TEST
Economic and Societal impact Update	For this section please refer to D6.2 cpt. 2.5 and to D8.5 cpt. 4.1
Qualitative Business Impact Evaluation Update	Since there was an update in the last SH meeting in Dec 2020 we collected some feedback from the SHs. The output provided by the Driving Safeguard is being explored by SIS' SHs to address the two main businesses goals: • the need of more accurate and transversal driving feedback for drivers, to be used in the Car Pooling market or in any market which requires a normalized feedback for any drivers. • the need of an estimation of the global driving risk associated with a fleet or with a limited geographic urban (or metropolitan) area, as a sum of individual risks of any single drivers on the road. For each of the individual risks there is also the need to define a main component feature set that expresses the greatest driving risk. Then each of them has to be matched, with a IF-THEN-ELSE statement, as a model-driven mitigation strategy of the driving risk. The output provided by GoGreen Wiz can be applied in both of the Car Pooling and the EV business areas. SH are evaluating the impact of the tool, after the last performed SH meeting for the Pilot1 that appears to have benefits for the following markets: • Connected Cities administrations that want to implement the Vehicle to Grid application in order to balance the electricity demand with the load of the network. • big Private companies who want to develop their own Car Pooling service for their employers to cut the company fleet costs and obtain a better mortgage from the fleet of cars they own. • Commercial fleet owners, who want to switch a percentage of their fleet from ICE vehicles to electric vehicles and specialize them in urban paths, maximizing the profit from that total cost of their fleet ownership.

Table 4-2 Pilot 1 – Learning Outcomes & Conclusions

Best Practice Description	The best practice for addressing the Pilot1 targets is partially described in D8.5 in the learnt lessons section. From a higher level point of view, another lesson can be learnt, that is that the choices made in the very beginning of the designing phases can greatly accelerate or slow down the exploitability of the product developed during the project. In the Track&Know project the designed architecture and the adopted technology are very reliable and very widely used for any historical and streaming application over big data. This has allowed the Pilot1 to be very well integrated to every existent production environment. The market analysis performed in D7.2 has also shown how the partial B2B selling modality, using the software environment of the SHs, that is prompt to escalate, as well as its customer services and installations services that are already active, permits better sustainability of the services, shorter time to market and a better scalability.
Reference Objective(s)	The best practices can be applied for all the three above defined use cases (UC1, UC2 and UC3) since each of them uses the same pipeline and the same toolboxes to address the requirement of the case.
TRACK&KNOW Solution	For this section please refer to the D6.2
Post-TRACK&KNOW Enhancement	For this section please refer to D6.2 section: “ future works” and to D8.5 cpt. 4.2
Investment	As already said in D6.2 cpt3.4 for the Driving Safeguard service another blind test analysis should be performed before going into production. For the Go Green Wiz service and industrialization investment is needed to re-test performances in SHs environment and of course to perform UATs with SHs.
Expected Impact	SIS is waiting for SH feedback. Hopefully part of the T&K toolboxes will be integrated in some SH software environments as shown in D7.2 “Pilot 1 business model considerations”

Table 4-3 Pilot 1 - Proposed Refinements

Refinement Description	At the moment KPIs are not below the set target, however they can just be inferred by the results of the model. Referring to D6.3 cpt. 2.5, it is clear that some parameters are still missing and moreover they cannot be calculated in the Track&Know project, because the provided dataset is historical and it doesn’t have any collected feedback for the 2 services in the 3 business areas. So, due to privacy settings no feedback could have been collected. This is the main reason that leads the Pilot1 to have more investments for validation activities both for the Driving Safeguard and for the GoGreenWiz.
Improvement	The best use of most of the Toolboxes and Pilots of the Track&Know project could be reached in both the B2B selling modes: the standalone deploy and the integrated platform deploy. However, some toolboxes are tailored to be integrated in the platform and used just in given Pilots; they should rather be used as a standalone or with different sampling rates streaming. An improvement in this way will be very valuable and hoped.
Post-TRACK&KNOW Action Plan	A high level action plan for the Pilot 1 acceleration could be to invest in the GoGreenWiz finalization and start to collect new feedback and new data to enlarge the data warehouse.

	In the meantime a second research validation (with drivers' feedback) can be run for the Driving Safeguard service that is the most mature of the two software tools but it needs more validation.

Table 4-4 Pilot 1 – Conclusions & Economic Benefit Analysis

Conclusions	
Conclusion	Driving Safeguard is the most mature software but it needs more validation tests over a subsample of the dataset which can benefit from real-time drivers' feedback. An UAT test phase with SHs it is expected for the both Driving Safeguard and Go Green Wiz as well.

4.2 Healthcare Service

Table 4-5 Pilot 2 - Objectives & Operational Measurements

BC1 / Objectives 1-4/ UC1-4	Analyse service and propose optimisations Bobj. 1.1: Capture the service operation across a geographical area over a given period Bobj. 1.2: Gather the actual requirements from multiple data sources Bobj. 1.3: Run simulation scenarios to select the most effective service and equipment distribution (within its constraints) Bobj. 1.4: Test the proposed model in a real-life pilot where the OSA service implements a proposed model and tests KPIs
Description	The main goal of the service is "to ensure patients get the right care, in the right place, at the right time and with the right resource". Thus, BC1 analyses service function, demand vs. service provision, enables the user to test different service configurations based on different demand scenarios and to select one configuration, which should result in effective resource utilisation. The selected configuration is tested in real-life scenario, the resulting data undergo the service analysis to measure the improvements gained. The four objectives define analytical and experimental actions, which are executed in as many cycles as needed to yield the necessary answers – as new insights are gained from a cycle and/or new data batches are analysed.
TRACK&KNOW Applied Concepts / Innovations	The concept of analysing heterogeneous data from different sources, such as weather, traffic and demographic data, in connection with the hospital data, in the context of referral and demand analysis for one geographical area is innovative. To the best of our knowledge this is a first-time application in the health care domain of day-to-day care provision. The concept of using geo-intelligence in this context is new as well, especially the generation of maps which visualise different demand scenarios. The application of advanced visual analytics tools to identify patterns of attendance is also new in the domain. The preprocessing of the appointment data, especially the trajectory reconstruction tool which converts postcodes to travel distances is unique in the domain. The automated pipeline, which processes the data across different toolboxes is first-time application, in particular the addition of the enrichment tool is unique.

	The application of the p-median method to facility positioning is new in the domain, also the actual concept to reposition facilities to be closer to the demand areas is also new in health care. The simulation tool for location/allocation, along with the demand scenarios and the dashboard for the operator is first-time application in the health care domain of day-to-day care provision. All of the above concepts and applications of either existing or newly developed tools are unique in their first-time application. The outputs have demonstrated that the tools add value for the analytics of a health service. See also Table 5 in section 6.2 of D6.3 for more detail.
Measurement Method	Quantitative KPIs: KPI1 – reduction of travel distance – measured by a direct comparison between travel distances during different geographical service configurations. The dashboard enables automated calculation of the distance in the different scenarios and displays both distances at once. KPI2 - cost efficiency – is based on the number of facilities required to operate in the service in locations which best match the demand and have the best proximity to the patients in the area. The dashboard enables automated calculation of the optimal number, positioning for different demand and distance scenarios. It displays the outputs distances at once. KPI3 – no show rate – compares the % NoShows between different data batches, comparing service configuration – see p. 44 and 45 in D6.3. The actual numeric output is a simple calculation of % once the data batches have been separated and and compared between batches. The interesting aspect of this work is the actual visual analytics of NoShow factor research reported on p.41 and 42 of D6.3. KPI4 – CO2 reduction is derived value from KPI1 and trails this metric, with a calculation of CO2 per km that could be potentially saved for the appointments over a period. Overall, the KPIs were attained with minor deviations.
Initial (Baseline) KPI	KPIs 1 and 4 were not available at project onset, but targets for improvements of the following were set: existing travel distance – value gained after data processed by Track&Know tools. Existing CO2 emissions of the same, derived from distance. KPI2 existing number of facilities = 22 was known at project start and a reduction target was set. KPI3 no show rate had been estimated at project start from hospital data by the service managers. However, following the analyses performed, it was shown that the estimates of 18% were no longer correct and that the last period analysed had a rate of 22% !
Mid-term TRACK&KNOW KPI	N/A
Final TRACK&KNOW KPI*	**KPI 1** travel distance = result ~50% reduction (target 25%), if patients are allocated their closest facility, further 24% if the facilities are relocated, >60% using alternate delivery methods via simulation tool.

	KPI 2 cost-efficiency = result 18%-54% reduction (target 20%) via simulation tool. Based on reducing (by 4-12 facilities) and optimally placing the remaining facilities. **KPI 4** CO2 was derived from the savings in KPI 1, there was no target set, as it is proportional to the distance. Result – for a 4.7 km saving of distance per appointment and for a total of 42000 appointment trips, the reduction of CO2 emissions would have been **47 376** kg CO2 (for petrol cars) – a reduction of 25% based on assumed mode of travel and simulated distances. **KPI 3** NoShow rate reduction. Not measured via real life new data but measured on historical data as contingency. See also chapter 8 Deviations from Plan in D6.3
Economic and Societal impact **Update**	The societal-economic impact has two interlinked perspectives: Health outcome improvements through better access to more individuals in need for treatment – less complications such as heart attack and stroke, less deaths, less road traffic accident injuries due to untreated OSA. The improvements are also linked with economic gains – less societal costs for treating the above conditions and disabilities, less sick days in the work force. Health care cost improvements – currently resource is significantly wasted – ineffective clinic locations with their associated overhead and staff costs, 22% No show rate – which additionally wastes resource while there are patients on the waiting list. In addition, one important impact is generation of evidence and new knowledge on: • Areas of demand • Insufficient coverage of demand • Areas of ineffective OSA clinic activities All of the above (and many other insights as listed in D6.3 Results) provide evidence to health care managers, which helps initiate service change, new public health measures, as well as audit any new configurations on an ongoing basis. It is important to understand that Track&Know is not a tool for a one-off analysis, but that it supports both any historical analysis as well as any new service changes with business-intelligence that was not available before. Unlike most other business domains, health care services tend to be very cautious about implementing changes to service, as there is solid evidence required to support decision-making, since lives and health are at stake. Concerns about patient safety, information governance and many other requirements pose barriers to ill-justified decisions. Track&Know is the first of its kind tool that provides a new way for looking into service delivery.
Qualitative Business Impact Evaluation **Update**	The stakeholder analysis of pilot 2 has identified the following large groups of target stakeholders: • OSA Service providers (Hospitals, Clinics, GPs) • OSA Service payers (Department of Health/CCGs, Insurances) • Medical, public health and health management researchers and societies • Equipment manufacturers (diagnostic and treatment equipment)

- Patients and patient organisations (OSA, Crash victims)
- Regulatory agencies (DVLA)
- Policy makers (EC, WHO)
- The wider society

Feedback from stakeholders has been collected throughout the project time via multiple stakeholder meetings and webinars.

Overall a wide range of stakeholder categories has been reached in the pilot site and beyond across the UK, e.g.: clinical service leads, patient booking managers, R&D clinical trial director, patient organisations, CCG (payer) representatives, the wide public, potential collaborators for future work, Public Health researchers, Public Health England, technical researchers, health care management opinion leaders, consumable suppliers for OSA, professional medical societies (key opinion leaders), community doctors, GPs.

Comments in brief:

Applicability across health care services:

“pacemaker clinics for yearly checks” – Royal Papworth Cardiologist

“small diagnostic urology procedures” – Cambrige Uni Hospital Urologist

“disability equipment services” - Cambrige Uni Hospital Occupational Therapist

“yearly health check mobile clinics / screening procedures” – GP Peterborough

Usability

“The simulation tool per se seems very useful for operations managers and decision-making. The other analytical steps are best run by a technical expert who would guide the clinical users” – Service Manager Rheumatology Devon NHS Trust

Transferability:

“useful approach for clinical trial re-siting to reach more patients, as it is known that patients may not enrol in trials simply because of travel inconvenience” – Cambridge Uni R&D Clinical Trials director

“Can be deployed not only for health and social services in the community, but also for domestic abuse victim centres” – Uni Bedfordshire public health researcher

Funding:

“If tool can be used within the NHS firewall, it would be deployable across several services and it would add value and savings – worth considering” – CCG Director

“the geo-intelligence would be useful for private hospitals, as facility contractor to the NHS” – private orthopaedic surgeon

Suggestions for enhancement of impact:

	"NHS digital is implementing tools for integrated care management, which maybe complementary, worth looking for synergies, plus it would be a great target to collaborate with them" – Yorkshire Ambulance NHS officer and project manager "Scalability would be 'easy' if tool implemented at NHS central office as opposed to each NHS – IT expert system implementations "Meet with pharmacy chain owners to explore the opportunities they see as to what service could be provided via a pharmacy as third-party location" – consumable supplier ***Potential barriers*** "The dashboard looks easy to operate, however we are not keen to learn using it or providing feedback until we know for sure that our managers have decided to implement it" – booking staff from PAP "Patients may not accept being booked to the closest facility as they may have a preference, it cannot be a mandatory process" – ethics expert Uni Lancaster Finally, since the Track&Know project served as a foundation for the 3 UK partners to respond to the COVID19 crisis with a proposed set of additional tools for intelligent referral allocations, in the BACKLOG project the above feedback and the impact have been additionally validated.

Table 4-6 Pilot 2 – Learning Outcomes & Conclusions

Best Practice Description	To reframe the appointment data into mobility data by creating trajectories and performing a geospatial analysis.
Reference Objective(s)	All 4 KPI's were addressed through this first step (3 KPI's were attained, and valuable insights were gained for the 4th) and key insights were derived from the location-allocation geospatial analysis
TRACK&KNOW Solution	The journey reconstruction pipeline The enrichment pipelines The BDA Toolbox (Genetic p-Median solver)
Post-TRACK&KNOW Enhancement	The next table will show how some of these components are being used in spin-off projects and in response to the COVID-19 Crisis.
Investment	External funding has and is being sought after to make these tools more mature and make them available on the UK Governments cloud for public services including the private NHS' Network. Potentially different departments amongst the NHS may pay to use the service.
Expected Impact	**Service Optimisation Impact** The project results will not only have an **impact** on improving the efficiency of the service under study but will also motivate a nationwide review of sleep disorder testing service provision. Considering the increasing worldwide burden

	of OSA, the impact will be at international level as well. In addition, many other health care services have similar business cases, delivering care across different facilities over a geographical area that would benefit from location allocation optimisation. For example, pacemaker check clinics, urology clinics, diabetes clinics and many others are operating in the same context and have similar challenges that cannot be resolved with traditional IT tools. In particular, the innovative analytic methods deployed on the patient data, combined with additional relevant data (e.g., transportation networks, administrative boundaries, population characteristics) to derive mobility characteristic data, open new avenues for health service optimisation. Integrated care is one large area which will benefit from using the innovative optimisation approaches. **Impact on Citizens and Society** Improving access to health services brings on health and cost benefits to society by preventing complications, reducing disability and even mortality. Effective and accessible health service facility location has the potential to reduce individual and public health burdens. Over time, increased rates of patient screening, diagnosis and treatment associated with improved access might decrease incidence of health problems and capital expenditures. This applies to undiagnosed OSA, but likewise to many other conditions associated with health problems if undiagnosed and untreated, such as diabetes. In addition to the health and cost benefits for society, there is also a very important aspect of citizens' satisfaction with the care provision. When health organisations have the opportunity to audit their service provision in an innovative way and when the data enable patient-centred analysis under consideration of the demand and equal access of disadvantaged groups, then this naturally will increase the trust in the health system. Less waiting time, less travel distance and less hassle to access care will positively impact on citizens' participation in the care process. **Impact on Funding and Planning Authorities** Although overarching bodies, such as NHS Digital, the Department of Health etc. have implemented sophisticated tools, the Track&Know project has shown that significantly more insights can be extracted from existing data sets if big data analytics would be deployed. Leveraging the value of the information which has been collected by health care organisations will enable a new approach to auditing effectiveness and efficiency and will also provide a solid foundation for transparent decision- making for planning and funding. Moreover, a strong case can be made that new methods for planning resources,

	deploying resources according to demand are necessary and well-placed in time, especially in view of the disruptions caused by the COVID-19 crisis. **Strengthening competitiveness of Track&Know partners** As has already been reported, the innovative tools and the health care business cases have triggered a positive response by stakeholders and engagement has been pursued by the SMEs for further product marketing. In addition, the two SMEs in the health care pilot were able to respond very fast to the COVID-19 call by InnovateUK and to leverage the outputs of Track&Know as a foundation for additional tools to overcome the waiting list challenges.

Table 4-7 Pilot-2 - Proposed Refinements

Refinement Description	A refinement per se is not proposed. However as per deviation report D6.3, the live deployment of the selected service configuration should be executed as soon as the crisis recovery allows, followed by a KPI review. Having said this, other factors may also play role in the new normal and given the waiting list backlog, going forward, it seems most useful to trail Track&Know analytics with BACKLOG project analytics for maximum impact.
Improvement	It would be very user friendly if in the future the analytics could be done all in one place. Ideally a user should have a virtual connection to the experts and discuss the outputs of the different offline tools, which are important for some of the decision making as to what goes into the platform pipeline and why, what is expected. Hence the service could provide a virtual analytics room for collaborative use case – tool deployment planning and output analysis. These are all steps prior to the dashboard that could be added to the day-to-day service.
Post-TRACK&KNOW Action Plan	The action plan is already under implementation. The pilot 2 partners CEL, PAP and ILS have successfully applied for an INNOVATE UK grant for referral management with geo-intelligence tools to support the NHS during the COVID19 crisis, in the waiting list clearance. The project is an exploitation activity for Track&Know concepts and tools and the first phase was completed on the 30.11.2020. Final stakeholder events for both projects have been held and promotional materials for post project end have been prepared. CEL has contracted UKCloud as safe IT service provider with reach into the NHS systems. Subsequently it has received additional funding for extension of impact and bridging the valley of death. From 1.1.2021 – 31.3.2021 the following business development activities will take place, which will run in parallel for Track&Know and Backlog. Spin-off creation between the 3 partners (or CEL and ILS, if PAP has delays) Allocation of the go-to-market budget to specific activities as per work plan: promotional materials, business strategy and start-up strategist activities, compilation of a CRM to have a list of targets and timetable, intensive networking for 1:1 pitching which is felt to be more effective to actually engage stakeholders beyond the initial feedback, cloud provider costs for the data set simulations and validations, any UI refinements, website – additional “How to” videos and FAQs.

	Expected outputs: At least 3 NHS or related services should provide their data to BACKLOG for analysis. Generation of evidence of user feedback and cost savings. Validation of proof-of-concept applicability and benefits for service. Other outputs which will be pursued but likely to need more time beyond 31.3.2021: Investment into spin-off Contracts with NHS or related services. The strategy is for both project outputs to be promoted at the same time. BACKLOG outputs are smaller and more tangible, easier to pitch, the system operates from one place and addresses the immediate national needs. Thus, they should be pushed first, upon engagement of stakeholders, the Track&Know project outputs will be promoted and their value in bringing unique geo-intelligence and ability to analyse heterogeneous data will be highlighted.

Table 4-8 Pilot 2 – Conclusions & Economic Benefit Analysis

Conclusion 1	The NHS (or the very least the different services and CCG's) have never been able to see their own data in this geospatial context. Therefore, the organically grown services are not as effective as they can be. There is a market for a tool that different hospitals, services and clinical commissioning groups can visualise and simulate their catchment cohorts. This will enable efficient and cost effective service growth in the future.
Conclusion 2	Previous assumptions regarding patient behaviour have not been entirely accurate – distance does not play a factor in patient attendance. Weather has a stronger correlation with no-shows. When visualised there are clear gaps, not only in service-delivery but also in patient referrals. When analysed against socio-economic and propensity data a pattern emerges showing a lack of equitable access to high level services. Fixing these gaps will have long term societal benefits in terms of community health and save the NHS money.

4.3 Fleet Management

Pilots' performance assessment, lessons learned & value propositions collection, involved an iterative process carried out throughout the life of the project, to not only collate operational measurements, learning outcomes and conclusions, but also drive refinements following the submission of the respective deliverables.

The following four tables are the bases by which each Pilot has documented higher level gains from the use of tools in Track&Know. Each table cell on the right provides a detailed description of the requested input.

Table 4-9 Pilot 3, Fleet Management - Objectives & Operational Measurements

Objective # / UC#	FMUC-1 - Predictive maintenance (FMUC-9 – Vehicle's trips
Description	Being able to predict the next maintenance task with location-based data of service points only.
TRACK&KNOW Applied Concepts / Innovations	Predictive maintenance requires semantic annotation of data that contain service events; such information was not provided by users on the platform. However, by

	observing IMN networks of POIs that are service points and the time / distance between these points we estimate the next visit, hence the next maintenance task.
Measurement Method	To reduce by 15% the service delays of vehicles.
Initial (Baseline) KPI	No available process on existing platform
TRACK&KNOW KPI*	Partially achieved KPI of prediction of maintenance tasks. An expected 15% improvement is envisioned but with current data and experiments this cannot be quantified.
Economic and Societal impact **Update**	There is no direct economic and societal impact for this use case. During simulation data indicated that vehicles visited service points on average the same time of year and after a proportional travelled distance. The accuracy was 1-2 months before after the predicted maintenance; this could be used as an estimation for the next service. However, the output of the tool is used for another identified case (FMUC-9). This tool can be used to visualize and offer a quick overview of how a vehicle is operated throughout a time period.
Qualitative Business Impact Evaluation **Update**	This tool can be used only as an indicator and not as predictive maintenance tool.

Objective # / UC#	FMUC-2 - Anomaly detection, reduction of false alarms
Description	During online data flow detect outliers (bad GPS reception, improper installation etc.) Clean up erroneous GPS signal, duplicate data (online) and out of temporal order data.
TRACK&KNOW Applied Concepts / Innovations	Utilizing the data streaming capability of the TRACK&KNOW, data is sent via BDP toolboxes. GPS data cleansing and trajectory map-matching flows are used.
Measurement Method	To detect erroneous packets (out or temporal order, duplicates, erroneous coordinates, speed errors) and find the closest road coordinate on a map.
Initial (Baseline) KPI	Only zero coordinates were detected
TRACK&KNOW KPI*	Achieved KPI
Economic and Societal impact **Update**	There is no direct economic and societal impact for this use case. During simulation erroneous packets injected in the pipeline of the processing of data and the system successfully identified and marked as erroneous. Users don't see those packets on their monitoring GUI hence no confusion occurs.
Qualitative Business Impact Evaluation **Update**	End users enjoy better quality of their data which builds the trust the system users have towards this technology.

Objective # / UC#	FMUC-3 - Correlation of Fleet Data with external Weather and Traffic services
Description	During online data flow any device data packet arriving to the platform is enhanced to contain weather data.
TRACK&KNOW Applied Concepts / Innovations	Utilizing the data streaming capability of the TRACK&KNOW, data is sent via BDP toolboxes. Weather enrichment and POI (such as hot traffic jam points) are added to the stream data process.
Measurement Method	To include weather and traffic information at the output of the online process.
Initial (Baseline) KPI	No available process on existing platform
TRACK&KNOW KPI*	Achieved KPI
Economic and Societal impact Update	Weather and traffic (or any other POI) provide useful information during vehicle monitoring and what the how external conditions are at any given moment. During simulation data from testing vehicle where pushed to the platform and the output contained the expected information.
Qualitative Business Impact Evaluation Update	The product itself becomes a more "complete" product as it offers a more accurate picture of the vehicle and the road condition that it is being operated.

Objective # / UC#	FMUC-4 – Fleet costs reduction
Description	Devices send data that by looking at a single data point the data is correct; but when observing the changes of values through time and patterns emerge
TRACK&KNOW Applied Concepts / Innovations	Using a hot-spot analysis (Hot-spot Analysis BDA) the areas are marked for avoidance by the routing tool of ZEL, thus reducing time and fuel. Based on the common trajectories in vehicles (Distributed Trajectory Join BDP), the component is used to suggest ridesharing thus achieving reduction of costs.
Measurement Method	For vehicles that have common trajectories when not all are deployed there is a significant gain per day per vehicle. When 1 instead of 2 vehicles are used then the CO2 emissions is reduced almost to <50%. KPI Improvement due to BIG DATA: Identification of common routes for vehicles. Thus, reduce the number of vehicles on the road. Also finding hotspots (traffic points that vehicles are stopped or moving at slow speed) and marked as areas to be avoided contributes to the reduction of CO2 emission.
Initial (Baseline) KPI	No available process on existing platform
TRACK&KNOW KPI*	Achieved. Project KPIs: Fuel efficiency increase >10%, CO2 Emissions decrease >5% and Fleet fuel efficiency improvements >10%.

Economic and Societal impact Update	The proper utilization of vehicles that share same trajectories offers a significant economic and environmental benefits, since non-needed vehicles are not driven. During testing for customer with salesmen and customer facing workers, several vehicles where identified with similar trajectories. This lead ZEL to build a GUI that displays this relation and gives a clear understanding to a fleet owner that co-sharing is a possible solution for cost cutting.
Qualitative Business Impact Evaluation Update	Beyond the economic benefits for the customer this case also helps customers to improve its social responsibility.

Objective # / UC#	FMUC-5 - Fleet downtime reduction
Description	Devices send data that by looking at a single data point the data is correct; but when observing the changes of values through time and patterns emerge
TRACK&KNOW Applied Concepts / Innovations	Using a pattern recognition tool CER, to identify device data flows that are not expected even though if a single packet from a device has no errors. ZEL uses the component output that has matching patterns of erroneous flows – flows not expected.
Measurement Method	To find patterns of erroneous devices based on engine status, speed, position and satellite reception.
Initial (Baseline) KPI	No available process on existing platform
TRACK&KNOW KPI*	Achieved
Economic and Societal impact Update	The system was fed with stream of data from working and erroneous device/vehicle installation. Those device / vehicle configurations did not offer proper data that could be used by a flee operator. Once the issues identified and fixes performed, monitoring of the fleet was accurate with valuable information. The cost benefit for this tool is the valid operation of the fleet management product and its value delivered from proper working devices.
Qualitative Business Impact Evaluation Update	This tool is of high value for support team. Operators instead of looking at graphs and arrays of data this tool offers a direct output of possible erroneous devices. The operators focus directly to the data that need further investigation thus resulting less work time and help keep the data of high quality from properly functioning devices.

Objective # / UC#	FMUC-6 - Fleet response time improvement
Description	This component predicts then next possible position of a vehicle, this feature is leveraged in order the platform to act before the vehicle arrives to the future location.
TRACK&KNOW Applied Concepts / Innovations	Future Location Prediction (BDA) Trajectory Prediction (BDA)

Measurement Method	To be able to detect the next vehicle location within the next 60 - 120 seconds and accuracy of 15 meters
Initial (Baseline) KPI	No available process on existing platform
TRACK&KNOW KPI*	Achieved
Economic and Societal impact Update	The ability to predict a vehicles next position, without knowing the destination, has the benefit of acting beforehand. This tool covers the need to notify store owners of the city center of Athens to take out the trash, minutes before the sanitation vehicle arrives. This is a benefit over removing trash and letting it on the street for a larger period of time.
Qualitative Business Impact Evaluation Update	This socially responsible case, improves the quality of life for people commuting in areas where trash are removed for a small amount of time.

Objective # / UC#	FMUC-7 - Improve driver behaviour and reduce accidents
Description	To use GPS data to categorize drivers as their driving style could be risky or not.
TRACK&KNOW Applied Concepts / Innovations	For this process a specific tool was developed – Driving Profiling (BDA). This tool decomposes each part of a vehicle route into small slices. Once each slice is classified, we cross-reference this classification with any relevant events from the accelerometer (from devices that have such sensor), the colour the corresponding the event. The result is the following color-coded plot (each colour is an event), each dot being a trajectory slice that has one or more harsh events. Harsh events are the events where the acceleration measured by the device are more that the following list. This list is provided by the manufacturer of the devices as Eco / Safe driving settings.
Measurement Method	To classify drivers based on their driving style.
Initial (Baseline) KPI	Driver behaviour on existing fleet management platform did not have any relevant KPI. Drivers are classified per harsh events (when acceleration, breaking or cornering occurs more than a specified g value)
TRACK&KNOW KPI*	Achieved
Economic and Societal impact Update	The use of this tool offers the ability for a fleet owner to visualize parts of trajectory where the driving is more likely to be risky or is considered different that the rest of the fleet. With this information a driver can be educated to be a better driver. The impact of better driving behaviour on the streets lead to a much safer roads.
Qualitative Business Impact Evaluation Update	The use of a tool that can train a driver to become better is a socially responsible act. Fleet owners have a tool that can be leveraged to monitor driver behaviour and a reference point for improvement.

Objective # / UC#	FMUC-8 – Real time vehicle route calculation
Description	Devices send data that by looking at a single data point the data is correct; but when observing the changes of values through time and patterns emerge
TRACK&KNOW Applied Concepts / Innovations	Using a pattern recognition tool CER, to identify device data flows that are not expected even though if a single packet from a device has no errors. ZEL uses the component output that has matching patterns of erroneous flows – flows not expected.
Measurement Method	To find routes of a vehicle based on start and stop of the engine.
Initial (Baseline) KPI	Offline process initiated each time user required data.
Final TRACK&KNOW KPI*	Achieved
Economic and Societal impact Update	This tool generates a report useful to a fleet owner; since the aggregated details are easy to a human to understand.
Qualitative Business Impact Evaluation Update	This tools is essential to understand vehicle routes, the quality of clean data and clean pattern detection offer a valuable tool.

Table 4-10 Pilot 3 – Learning Outcomes & Conclusions

Best Practice **Description**	At ZEL we approached each use case (goal) as the standard software solving solution. First the case/problem itself is clearly defined from a business / end user perspective. Once this is defined then the second step is to determine the right methodology and software tool. This task was performed on bilateral discussions between ZEL and technical partners. The tasks included demo use cases (toy stories), proof of concepts with live data and an Agile methodology of multiple interactions between stake holders and solution providers. This process is considered as best practice because it focuses on the problem itself, insists on direct cooperation of stake holders and solution providers and via continuous interactions the solution is accepted by both parties with the first agreed acceptance criteria.
Reference Objective(s)	All cases were treated based on best practice guideline.
TRACK&KNOW Solution	ZEL use cases rely on the platform itself (Kafka streams) and the following toolboxes: • Individual Mobility Network (BDA) • GPS data cleansing (BDP) • Trajectory map-matching (BDP) • Weather Enrichment (BDP) • POIs Enrichment (BDP) • Hot-spot Analysis (BDA) • Distributed Trajectory Join (BDP) • Complex Event Recognition (CER)

	• Future Location Prediction (BDA) • Trajectory Prediction (BDA) • Driving Profiling (BDA)
Post-TRACK&KNOW Enhancement	ZEL envisages to fully adopt all relevant toolboxes and plans to support a further deployment solution: • Fully integrate the TRACK&KNOW solution as part of its software development lifecycle. • Utilize the TRACK&KNOW solution's infrastructure (Kafka streams etc.) to other flows than of those of the above-mentioned toolboxes • Work with research partners to further enhance the toolboxes
Investment	Due to the nature of the platform a minimum investment, both in infrastructure and human resources, is needed because the learning curve for knowledge adaptation is insignificant and costs for infrastructure is covered by the current non-utilized system capacity. An estimation of no more than 10K Euros is envisioned for the first system users and is expected to raise proportionally to the added number of system users (users and vehicles)
Expected Impact	Two are the major expected impacts that this platform will bring to the fleet management product. • The first is the trust that will bring to the project the quality of the data (online error cleaning and error detection). This cannot be quantified in economic terms, but it is considered important for the product longevity and customer trust. • The second are the new ML based tools that offer insights for costs reduction, driving analytics and future predictions are utilized to bring those benefits to solve real world needs.

Table 4-11 Pilot-3 - Proposed Refinements

Refinement Description	**FMUC-1 - Predictive maintenance** To predict next maintenance tasks. There is no semantic annotation of maintenance tasks since fleet owners don't enter such information on the platform. However, by observing IMN networks of POIs that are service points and the time / distance between these points we estimate the next visit, hence the next maintenance task.
Improvement	To collect from users annotated data and cooperate with data scientist to extract predictive maintenance tasks.
Post-TRACK&KNOW Action Plan	ZEL has already hired data scientists to work on various project including predictive maintenance tasks. A cooperation with the industry is expected for collaboration in predictive maintenance tasks.

Refinement Description	**FMUC-7 - Improve driver behaviour and reduce accidents** To improve driving behaviour which will lead to less accidents.

	Driving behaviour and accidents is a complex task to be addressed by location (GPS based) data. However, using data analytics we classify each driver's trajectory and compared to harsh events the route is given a class (R,A,G). A fleet owner then uses this tool in order to describe to each driver the part where harsh events occurred and over time this could lead to training tool for less harsh event driving.
Improvement	A significant improvement is to test new modalities (extra sensors, cameras, road cameras etc) to gather new data and work on a more complex data model.
Post-TRACK&KNOW Action Plan	ZEL keeps ties with research bodies and with cooperation with in-house personnel, the use case will be further searched and improved.

Table 4-12 Pilot 3 – Conclusions & Economic Benefit Analysis

Conclusions 1	The platform itself is a paradigm to move more flows on Kafka streams, currently implemented differently at ZEL products
Conclusion 2	Customers will benefit from quality data, resulting higher trust in the product and Big Data technologies in general.
Conclusion 3	By utilizing cost saving suggestions, the customer will benefit economically and also the environmental impact is considerable as CO2 are reduced for each vehicle not operated.
Conclusion 4	Fleet owners and driving school instructors can benefit the visualization of categorized trajectories. Instead of looking mass data points, a user can pinpoint to the time and place of possible harsh events.

5 KPI's and Value Proposition

This section of the report provides an overview of the project pilots attainment of the KPIs and a summary analysis of the economic benefits and adoption of Track&Know from the pilot perspective.

5.1 Pilot Experiment KPI's

The table below summarises the attainment of pilot specific KPIs that the project had set out in the description of action as well as in D6.1. This is a synthesis of the detailed tables in the previous chapter and the respective pilot deliverables.

Table 5-1 Summary of the Pilot specific KPIs

KPI	Target Value	Measured Value	Comments	Means of Verification
Real time and historical data will be made available to Track&Know	>1.0 TB	1.23 TB or ~1 GPS/min/vehicle	For 3-years location-based data for a fleet of ~10,000 vehicles (resulting in ~4 bn records in 3 years)	Data stored in RDBMS
Fleet Management > Fuel efficiency increase	>10%	>10%	Common vehicle trajectories allow pooling of resources reducing the number of vehicles on the same route, thus increasing fuel efficiency.	Experimental
Fleet Management > CO2 Emissions decrease	>5%	>10%	Avoidance of hotspots and resource pooling (i.e. reducing number of vehicles) reduces the CO2 emissions.	Experimental
Car Insurance > CO2 Emissions decrease	>5%	> 6%-8%	According to the GoGreen WIZ an average potential 80% of ICE vehicle trips, in urban and metropolitan areas, can be avoided by switching to EV or by joining a Car Pooling (CP) service. A marketing analysis have to be performed in order to acknowledge the actual rate of EV switching and CP joining. The target is at least the 10% of the previous segmentation. Reference in D6.2 cpt.2.5.2 and in D6.6 cpt. 5.2.1.	Inferred by ML model outputs
Car Insurance > Economic profit from responsible driving behaviour	>10%	>10%	According to Driving Safeguard an average potential 40% up to 60% of car collision and accidents can be avoided. Further analysis, that includes drivers' feedback, have to be performed in order to acknowledge the actual rate	Inferred by ML model outputs

			of car collisions that can be avoided. The target is at least the 10% of the previous segmentation. Reference in D6.2 cpt.2.5.3 and in D6.6 cpt. 5.2.1.	
Car Insurance > Reported accidents decrease	>5%	> 4%-6%	According to Driving Safeguard an average potential 40% up to 60% of car collision and accidents can be avoided. Further analysis, that includes drivers' feedback, have to be performed in order to acknowledge the actual rate of car collisions that can be avoided. The target is at least the 10% of the previous segmentation. Reference in D6.2 cpt.2.5.1 and in D6.6 cpt. 5.2.1.	Inferred by ML model outputs
Asset Management > Service delays reduction	>15%	Unachieved	It is not possible to quantify the number of service delays reduction with the current set of data. However, a vehicle's mobility pattern can help pre-emptively schedule services reducing any possible delay.	
Health Market > Reduction of unnecessary travel	>25%	~50%, 24%, >60%	50 is just by allocating patients to closest facility, 24 is if the facilities were re-allocated optimally, and 60 is if the delivery model is changed to using pharmacies or stores as pick up and drop of points.	Simulations using real data, validated using data for upcoming appointments. Pilot also opened a new facility which had a predictable result
Health Market > BC1 KPI 2 Cost-efficiency gains	>30%	18-54%	Reduction of number of facilities (between 4 and 12) without significantly increasing patient travel can reduce costs. Scheduling appointments during periods of low no-shows.	Simulations of real data
Health Market > BC1 KPI 3 Reduction of No Show rate	10%	Unverified	Correlation of weather and season with no-show rates will help future scheduling decisions to avoid summer & 'good weather' periods.	Due to COVID-19 restrictions experimentation was not possible
Health Market > BC1 KPI 4 Reduction of CO2	>25	=25%	Derived from Reduction in unnecessary travel. Service would produce 47376 kg less	Simulations of real data,

	(mirrors KPI1)		of CO2 from a current 190512kg = 24.87%	Experimentation not possible due to COVID-19
Health Market > Data acquisition via the driving app	Y/N	Yes	The data pipeline developed by T&K was able to collect data from shift workers.	App put in the field
Health Market > BC2 KPI 6 Presence of sleep deprivation driving features	Y/N	Yes	Reported in D6.3, signals of affected driving detected.	Evaluation of real data

5.2 Track&Know Economic Benefits and Adoption

5.2.1 Auto Insurance and Innovative Mobility Services

The economic benefits of adopting the concepts of the insurance telematic services presented in the Pilot 1 solution are best represented using the GPI (Genuine Progress indicator) or the Carbon Footprint indicators based on the pilot's expected outcomes and KPIs.

Carbon emissions from anthropogenic activities and their impact on climate change are one of the main challenges for achieving environmental sustainability. Carbon footprint, as an environmental sustainability indicator, has been frequently studied to quantify the environmental performance of a product, individual, company, city, or country through LCA (life cycle analysis).

Achieving a CO_2 emissions decrease along with a positive GPI for certain areas is a very valuable result.

For the Carpooling and the Electric Vehicle Business Case, The Pilot 1 has shown a potential average of 60% up to 80% of trips that can be fairly substituted by EV trips or carpooling trips. In future works and also in production environments it will be interesting to investigate how much of that ratio can be actually covered. Setting a target of at least 10% of the found ratio, Pilot 1 has laid the foundation for a 6% up to 8% of CO_2 emission decrease in the three geographic urban and metropolitan areas considered.

In the insurance business case on the side, we can consider as background knowledge the average social cost of a crash accident and the average global costs per year and per State.

Since 2008, with the Directive2008/96/EC, the European Community has delegated its member states to perform a detailed estimation of how much they spend for car accidents every year including social costs and indirect costs.

In Italy, for example, The General Direction of the Ministry of Transportation has defined a method which takes the following into account:

- human costs, that are :
  - biological costs, i.e. the company's productivity loss due to a person's temporary or permanent inability to work after having experienced a car crash.
  - moral costs, i.e. the cost of all the indirect activity linked to the to the death or the recovery of an impaired person who experienced a car crash.
  - personal damage costs and other material costs
- Sanitary costs, that are :
  - emergency costs

  - recovery costs
  - assisted transport
- Other costs:
  - Administrative costs
  - Insurance costs
  - Legal Costs

That results in 24 Billion Euros of social costs only in Italy, for an average of 1.5M Euros for each dead person and even more for permanent impairments. The same parameter has been calculated by the European Transport Safety Council (ETSC) on a European base and it is an average of 2.11 M Euros for each dead person involved in a car accident, and even more for permanent impairments[2].

There are about 200 fatal crashes in metropolitan cities like Rome and London, and at least 10 times more serious accidents. In this scenario, as demonstrated in D6.2 it is possible to forecast and prescribe risk mitigation suggestions for about a half of them, with potential money savings that are about 100M of Euros of GPI. Future works will investigate how much of this amount of car crashes can actually be avoided with a target of 10% of the total, that, if confirmed, it will lead to at least 10M of GPI money savings. These results are further explored in the Track&Know exploitation plan (D7.2).

5.2.2 Healthcare Service

The health care pilot outputs are ground-breaking and innovative in terms of approach, tools and service.

- The public health intervention insights resulting from the project are very important to improve access to services and manage the high-risk areas with additional measures, such as education.
- Healthcare data are lagging behind other business domains in understanding how to apply technology for data analytics in some areas of service intelligence, constrained by governance issues, patient safety etc.
- Complex concepts are difficult to implement in health care, as the decision-making processes pose too many barriers. Small tangible solutions are easier to promote, get feedback on and succeed in engagement.
- The COVID19 crisis has posed challenges to the project, however it has also opened new opportunities to exploit the concepts and tools and has also validated their timeliness.
- Stakeholder engagement for complex results is better done on 1:1 basis, as there is better opportunity for meaningful interaction and explanations to achieve engagement.

5.2.3 Fleet Management

The ZEL – Fleet Management case was based on real customer requests and the vision of product owners.

This leads to a ready-for-production solution in respect of usability. ZEL can easily adopt the toolboxes developed not only based on business perspective but also on technical. End users such as fleet managers, drivers and support technicians can utilize the tools offered. The cases are described in more detail in deliverable D6.4 and mentioned as follows:

- Cleansed data. Erroneous data, out of temporal data are removed thus do not interfere with the following processing pipelines while reducing the platform strain – to process unwanted data.

[2] https://etsc.eu/wp-content/uploads/VPF-paragraphs-for-methodological-note-June-2018.pdf

- Map matched trajectories. Since all valid data is being map matched the trajectories are map aligned and offer better visualization.
- Enrichment process pipelines. Weather, POI, and traffic enrichment pipelines are used providing additional information to each data packet.
- Pattern detection. Early detection of erroneous behavior of devices provides a tool to immediate detect problematic devices.
- Future prediction. This powerful tool is used for user alerting of an imminent vehicle arrival and to replace discarded data by the cleansing process.
- Hot spot detection. Visualization of areas that could potentially incur delays (such as low speed traffic, traffic jams)
- Driver route classification. A tool to classify trajectories without the need of accelerometer which gives a fleet owner or a driving school instructor a tool to visualize parts of the trajectory were harsh events have most probably occurred.
- Mobility networks. A multifunctional tool that describes how vehicles travel over a period. This information is utilized at reporting services, possible for maintenance tasks and customer relation (how many times a customer is visited, time it takes, and distance travelled)

6 Conclusions

This deliverable completes the work carried out in Work Package 6 of the Track&Know project. Building on experiment planning and setup document (D6.1), this deliverable reports on the executions of the plan and the challenges faced by the Track&Know consortium. Despite a change of pilot partners, the introduction of GDPR during the life of a project utilising sensitive PII data, and a global pandemic, the project and it's three pilots were able to utilise the technical assets and advancements to answer critical business-related questions that were previously not possible.

Most of the KPI's associated with each of the Pilots were either met or exceeded. In some cases, only simulation was possible as putting experiments in the field for validation were not possible. The flexibility of the Track&Know platform and the toolboxes enabled data from three different domains to be processed, analysed, and visualised. Some of the data was of large volume (order of terabytes), some large velocity (thousands of messages / minute), and some had significant variety (GPS with other attributes (weather, points of interest, medical, driver information etc.).

The existing commercial pilot partners have already seen the benefits to the Track&Know platform and toolboxes and have already implemented components within their own business platforms. The public sector partner leveraged the Track&Know developments to guide the resumption of services as lockdowns eased during the COVID-19 pandemic. Several of the bridging partners have found exploitable and commercialisable pathways. A patent was also filed based on pilot applications of the Track&Know concepts.

From a pilot implementation process there were several key realisations and learnings:

- Big data projects need infrastructure providers who already have access to large systems, or significant money is required for either equipment purchases or cloud service. When budgeting projects with >1TB of data cloud gets prohibitively expensive. Either bare-metal infrastructure needs to be available or €35-75k is required to continuously work with the full dataset.
- Bridging Partners, those that speak the application domains language and can translate these to computational technical terms, are key to the success of implementation. Academia and software specialists cannot connect the dots between a business's high-level questions to the low-level components being built. The process doesn't work in reverse either. There can be two to three layers of requirements and functionality required to bridge these two needs and Bridging partners play a key role. They can conceptualise the intermediate layers enabling either the businesses to delve one level down or get the technical partners to design and develop one level up. Failing all that Bridging partners are able to produce 'quick and dirty' scripts to translate data.
- In person workshops and sub-group working sessions are required to propel development. In large consortia plenaries and teleconference do not progress development as assembling a smaller subset of the consortium in a room to actively work through key challenges.