Evaluation and analysis of driver's reactions using technology in different mobility scenarios

Tesis Doctoral

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Evaluation and analysis of driver's reactions using technology in different mobility scenarios

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Resumen

El uso de la tecnología relacionada con el mundo de la movilidad personal impacta en las personas, ayudándoles en algunos casos a mejorar su conducción, persuadiéndoles en otros para tener comportamientos menos agresivos en la conducción y por tanto cuidadosos con el medio ambiente o ofreciendo ahorros para el mantenimiento del turismo en otros. Esta tesis, basada en compendio de tres publicaciones en revistas indexadas, analiza la reacción de los conductores ante determinados estímulos tecnológicos, en distintos escenarios de movilidad, determinando así el grado de utilización y aceptación de la tecnología para conseguir ahorros en su movilidad y en definitiva una mejor conducción de los vehículos.

De manera más concreta, esta tesis está basa en analizar los impactos que la tecnología tiene en el ámbito de la movilidad en tres escenarios distintos; (i) el primero analiza la toma de decisiones de los individuos como consecuencia de uso de la propia tecnología. En este sentido, podemos avanzar que se ha estudiado el impacto de un sistema informático basado en los principios de persuasión que trata de concienciar sobre el gasto alrededor del mantenimiento automóvil. Este artículo demuestra qué principios de persuasión son más relevantes a la hora de influenciar a los conductores a mejorar su gestión de costes relacionados con la movilidad de su vehículo. Como conclusiones podemos apuntar que los principios más relevantes son el "self-monitoring", el "tailoring, personalization and Kairos" y los "reminders and suggestions".

(ii) El segundo verifica el papel de esta misma tecnología como motor de reducción del gasto en el ámbito de la movilidad. Para ello el artículo se basa en confirmar cómo un vehículo conectado a internet es eficaz en la reducción de gastos alrededor del automóvil frente a un vehículo convencional. Por tanto, este segundo artículo analiza si la tecnología emergente y embarcada en el auto (denominada vehículo conectado) juega un papel relevante en los gastos que tiene un conductor a lo largo de la vida útil del vehículo. La principal conclusión del artículo es que los vehículos conectados reducen un 18% los gastos de los vehículos no conectados.

(iii) El tercero artículo desarrolla un caso de uso para el mundo asegurador creando un clasificador de perfiles de riesgo. El análisis del comportamiento del conductor a través de datos convencionales ha sido una máxima hasta ahora para las aseguradoras. El trabajo que aquí se presente abre una nueva línea de investigación que permita que través de la recolección de los datos del automóvil se pueda modelar un sistema nuevo de precios y tarificación. En este sentido, este artículo analiza el desarrollo de un sistema de evaluación y gestión de riesgos potenciado con datos de geolocalización de los conductores y en función de los puntos de interés visitados por los asegurados. Nuestros resultados muestran que muestro nuevo sistema de clasificador del riesgo de los conductores basado en su geolocalización y ubicaciones visitadas tiene una precisión muy alta, constituyéndose así como una herramienta válida para que el sector disponga de un nuevo modelo de evaluación de conductores.

Abstract

The use of technology impacts in people, helping them in some cases, persuading them in others and offering savings in others. This thesis, based on a compendium of 3 publications in indexed journals, analyses the reaction of drivers to certain technological stimuli, in different mobility scenarios, thus determining the degree of use of technology to achieve savings in their mobility.

More specifically, this thesis is based on analysing the impacts that technology has in the field of mobility in three different scenarios; (i) the first analyses the decision-making of individuals as a consequence of the use of technology. In this sense, we can advance that the impact of a computer system based on the principles of persuasion that tries to raise awareness about spending around the car has been studied. This article demonstrates which principles of persuasion are most relevant when it comes to influencing drivers to improve their management of costs related to the mobility of their vehicle.

(ii) The second verifies the role of this same technology as an engine for reducing spending in the field of mobility. For this, the article is based on confirming how a vehicle connected to the Internet is effective in reducing expenses around the car compared to a conventional vehicle. Therefore, this second article analyses whether the emerging technology embedded in the car (called connected vehicle) plays a relevant role in the expenses of a driver. The main conclusion of the article is that connected vehicles reduce the costs of non-connected vehicles by 18%.

(iii) The third article published in an indexed journal develops a use case for the insurance world by creating a risk profile classifier. The analysis of driver behavior through conventional data has been a maxim until now for insurers. The work presented here opens a new option for, through the collection of car data, a new price system can be modelled. In this sense, this article analyses the development of a risk evaluation and management system enhanced with geolocation data of drivers and based on the points of interest visited by the insured. Our results show that the new risk classifier system for drivers based on their geolocation and visited locations has a very high accuracy & precision, thus constituting a valid tool for the sector to have a new driver evaluation model.

Acrónimos

ADAS	Advanced Driver Assistance System
DAS	Driver Artefact System
DB	Driver Behavior
GPS	Global Positioning System
HCI	Computer Human Interaction
IOT	Internet Of Things
ITS	Intelligent Transportation Systems
MIS	Management Information System
PAYD	Pay As You Drive
PC	Personal Computer
PDP	Persuasive Design Principles
RAM	Ramdom Access Memory
RPM	Revoluciones por minuto
TAM	Technological Acceptance Model
TAM2	Technological Acceptance Model 2
TI	Tecnologías de la información
TIC	Tecnologías de la información y comunicación
TRA	Theory of Reasoned Action
TRAM	Technological Readiness Acceptance Model
UBI	Use Based Insurance
V2X	Vehicle to Infrastructure

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CAPITULO 1: Introducción

1.1 Motivación y objetivos

El creciente desarrollo tecnológico, la globalización de los mercados y de la economía están cambiando profundamente el entorno de las organizaciones en cualquier rincón del planeta. Esta situación de cambio es una prueba esencial de la incorporación progresiva en las empresas de los actuales avances en materia de tecnología, telecomunicaciones, inteligencia artificial e incluso robótica. Hoy en día, la tecnología es capaz de compartir momentos de la vida cotidiana gracias a la universalización y la democratización. El principal ejemplo de ello lo llevamos en el bolsillo y es, por supuesto, el caso de los teléfonos inteligentes.

Uno de los beneficios que brinda la tecnología al tejido empresarial se basa en la interconexión, de manera tal que hoy en día, en cualquier momento y en cualquier lugar, podemos acceder a un universo de información lo que redunda en que seamos capaces de tomar más y mejores decisiones y sobre todo que tengamos la capacidad de hacerlo muy rápidamente, al menos mucho más que antaño. Además, el factor más relevante para las empresas está en poder disponer de la información del cliente en tiempo real para poder satisfacer sus necesidades en todo momento. La digitalización permite adecuar la oferta al usuario, pero también ayuda a que las industrias realicen el esfuerzo comercial en el momento en el que el cliente más necesita ese producto o servicio. Sin duda, hablamos de una nueva manera de entender un negocio. Hablamos de la revolución de los negocios gracias a la capacidad de procesar datos y convertirlos en información relevante para la toma de decisiones. En conclusión, , se ha evolucionado profundamente en la forma en que las personas se comunican y reciben o acceden a la información.

El impacto de estos cambios en el comportamiento del usuario final es uno de los focos de análisis de la tesis doctoral que aquí se presenta. De forma más específica, en esta tesis se analiza un caso de estudio de movilidad, ahondando desde distintos puntos de vista, el impacto que ejerce la tecnología en los conductores. De hecho, la tecnología puede jugar un papel relevante en la manera en que las personas reaccionamos ante distintos estímulos. En el ámbito de la movilidad, esta tesis pretende aportar aquellos elementos que son determinantes en cuanto a captar la atención del usuario con diferentes fines (p. ej., informativo, asistencial o para atraer su atención ante una alerta). También pone el foco en los factores que pueden ayudar a reducir el gasto de la movilidad en un vehículo particular. Por último, esta tesis propone un caso de uso de los datos para transformar estos en un modelo de utilidad para el mundo asegurador que permita cualificar a los conductores por su perfil de riesgo, tomando para ello datos de geolocalización y de uso del automóvil; es decir, caracterizar el vehículo y a su(s) conductor(es) en función de por dónde circulan y qué lugares son los que frecuentan con más asiduidad.

1.1.1 La evolución del automóvil

Según apuntan distintas fuentes, el coche del futuro es eléctrico, autónomo, compartido y conectado [1]. Desde la introducción de los teléfonos inteligentes, los usuarios han adoptado la tecnología como algo básico en sus vidas. Además, la tecnología es utilizada como canal para hacer las vidas de las personas más sencillas, más fáciles, más eficientes y seguras. Esa adopción de la tecnología por parte de los usuarios permite que en el caso del automóvil la utilización de nuevas funcionalidades no termine de crecer. Hoy el automóvil ha dejado de ser un elemento de transporte para pasar a ser un ordenador con ruedas. En este sentido, los propios fabricantes de vehículos comienzan a definirse ya como empresas de software y hardware, dotando a los vehículos con tantos chips que supera a cualquier ordenador de sobremesa [2].

Si analizamos la tecnología de un vehículo veremos que se trata de un conjunto de procesadores, con sensores, memoria Ramdom Access Memory (RAM) y módulos de conectividad que recuerdan más a los componentes de un ordenador de sobremesa que al propio coche.

Según el informe de Vodafone "The connected consumer 2030" [3], las compañías de tecnología deben entender que el coche es un espacio que ofrecerá oportunidades de entretenimiento, comercio y conectividad, si dejar pasar por alto la máxima de la seguridad en carretera. El vehículo pasa a ser un hardware de recogida de datos para su procesado y posterior gestión, tal y como ilustra la figura 1.

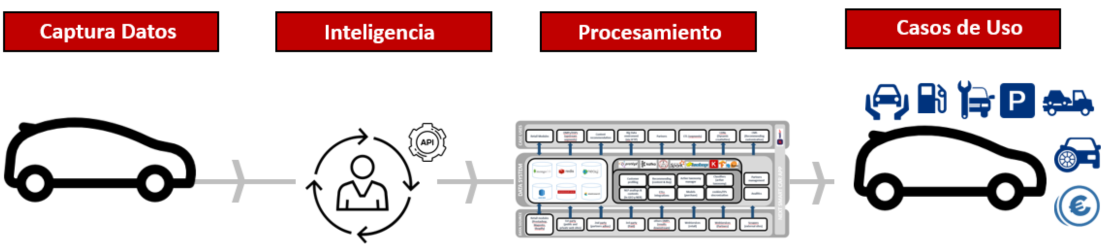

FIGURA 1. DE LA CAPTURA DE DATOS A LOS CASOS DE USO DEN EL MUNDO DEL AUTOMÓVIL

La captura de los datos del vehículo abre nuevas opciones al fabricante de autos para ofrecer nuevas formas de satisfacer los servicios del consumidor [4].

1.1.2 Los gastos asociados al mantenimiento del vehículo y su impacto ambiental

Según Grupo NEXT[1], compañía especializada en la recolección y gestión de datos de vehículos, el gasto acumulado por vehículo y año representa 2.000€. Cualquier variación sobre esta cifra

1 www.gruponext.es El autor de la tesis es fundador y consejero delegado de la compañía

supondría o un esfuerzo muy importante para los conductores o un ahorro significativo, máxime teniendo en cuenta que el salario medio en España es de 1.640€ brutos mensuales [5]. A nivel macro, con un parque de 24 millones de automóviles, hablamos de un mercado de gastos alrededor del vehículo de 50.000 millones de euros al año. Sin embargo, no todo es economía. No hay que desdeñar que el crecimiento de las ciudades (en la actualidad existen 43 megaciudades en el mundo con más de 10 millones de habitantes y se estima que para 2050 dos tercios de la población mundial habitará en urbes) requiere de soluciones innovadoras que aseguren el cambio hacia una movilidad más inteligente, más accesible y más sostenible [6]. Téngase en cuenta que el transporte por carretera es una de las causas principales de la contaminación del aire y de las emisiones de gases de efecto invernadero.

La movilidad inteligente es uno de los principales casos de uso que las llamadas "*Smart Cities*" han estado analizando y explorando en los últimos años, ya que buscan utilizar casos de uso basados en tecnología como medio de llegar a los ciudadanos y ofrecerles moverse de manera rápida, eficiente, sostenible y segura. La rapidez podría asegurar una mejora en la gestión del tráfico, la eficiencia viene determinada por el coste que supone la movilidad en vehículos privados y la seguridad se establece en la forma en la que podríamos contribuir a la reducción de la siniestralidad, que afecta a la eficiencia de los costes de la movilidad y que a su vez tiene impacto en el tráfico de nuestras carreteras y en la preservación del medioambiente.

En el mundo del transporte por carretera, la movilidad inteligente hace referencia a la tecnología que podemos embarcar en los vehículos y en la infraestructura que los rodea. Si atendemos a la tecnología que podemos instalar en un vehículo, esta tecnología consiste en dotar a los vehículos de dispositivos capaces de recoger información, analizar los datos que se generan y ofrecer información a los usuarios, sean estos conductores o peatones, tal y como se puede ver en la figura 1. Por todo ello, es crucial aprovechar al máximo las posibilidades que ofrecen los dispositivos móviles, para lo que es primordial contar con un aliado tecnológico de plenas garantías.

Esta tecnología debe ser desarrollada en un entorno que sea sencilla de utilizar por parte del usuario y en nuestro caso más ya que hablamos de conductores cuya principal misión es desplazarse sin riesgo. El presente trabajo está basado en la investigación y análisis de las bondades y beneficios que nos brindan la evolución de las tecnologías actuales en el ámbito de la movilidad. El impacto ha sido analizado desde 3 puntos de vista, estando a su vez relacionados entre sí:

- Comenzamos sobre la base de la gestión de la toma de decisiones en base al conocimiento, que explotamos como consecuencia del uso de la tecnología;

- Continuamos verificando el papel que juega la tecnología conectada al vehículo en aumentar o reducir el gasto habitual de nuestra movilidad;

- Concluimos con la realización de un análisis de un modelo de clasificador de perfiles de riesgo para el mundo del seguro de autos. Este modelo de clasificación, como veremos en esta tesis, nos permite distinguir a los conductores y establecer un ranking pudiendo determinar cuáles son mejores y peores conductores desde el punto de vista del riesgo siniestral para la aseguradora.

La tecnología puede jugar diferentes roles en relación a la forma en la que se presenta y se adapta a los seres humanos [7]. La interacción entre las personas y las máquinas está condicionada por cómo se presenta y afecta la tecnología a las personas y cómo de persuasiva es ésta, invitando a hacer una determinada acción o a dejar de hacerla. En este sentido, el papel que juega la tecnología es uno de los componentes más importantes en el modelo de relación entre las máquinas y las personas [8]. Analizar la capacidad de la tecnología en influir o persuadir a la mente humana es uno de los propósitos de investigación de esta tesis. Veremos a lo largo de esta tesis cuales son los principios que más influyen y por tanto que más hay que tener en cuenta cuando elaboramos un desarrollo tecnológico.

Desarrollar este concepto a través de una serie de principios de diseño persuasivo nos permitirá descubrir cómo se puede producir elementos tecnológicos que vayan a ser más o menos utilizados por los usuarios.

Todos los cambios en los modelos tecnológicos, como ya hemos adelantado, suponen una revolución en la industria automovilística. Uno de los exponentes que confirman estos cambios son los llamados *vehículos conectados* [9]. El reto para la industria del automóvil ya no es desarrollar vehículos más o menos potentes sino que está en hacer vehículos más eficientes, con tecnología suficiente para permitirles aprovechar nuevas formas de servicios que a su vez puedan suponer nuevas fuentes de ingresos para los fabricantes de coches [10]. Si partimos de la base de analizar un vehículo convencional hasta llegar al coche autónomo, el punto medio, tal y como ilustra la figura 2, es el coche conectado. Aquel que está conectado con la infraestructura, resuelve las necesidades del conductor y le ayuda en las gestiones que el vehículo necesita. Además, el coche conectado permite ayudar a transformar el vetusto parque automovilístico español, pudiendo hacer más eficiente la conducción de vehículos de más de 12, media actual del mercado español [11]. Esta eficiencia se enfoca desde dos puntos de vista; uno desde el ángulo del mejor posible mantenimiento del vehículo y otro por la manera en la que se recomiendan determinados usos y conductas en la conducción.

FIGURA 2. TIPOS DE VEHÍCULOS. ESTA TESIS SE CENTRA EN EL "COCHE CONECTADO"

Según Coppola y Morisio [12] hablamos de vehículo conectado como "aquél vehículo capaz de acceder a Internet, comunicarse con dispositivos inteligentes, así como con otros automóviles e infraestructuras viales pudiendo recopilar datos de múltiples fuentes en tiempo real". El vehículo, por tanto, deja de ser un sistema que sólo nos transporta y se convierte en un medio de transporte que puede ayudarnos a satisfacer nuestras necesidades diarias. Esta tecnología debe ser capaz de controlar algunos parámetros del automóvil e interactuar con el vehículo y su conductor. La tecnología subyacente se reconoce como IoT [13] y está relacionada también con la disciplina disruptiva de Big Data [14].

Hoy en día es ya muy sencillo controlar cuántos kilómetros se conduce un vehículo, cómo se conduce, qué revisiones necesita o qué consumo de combustible ha provocado. Esta misma tecnología va a permitir que los vehículos de nueva generación que incorporan tecnologías y servicios predictivos, por ejemplo, gestionen determinadas necesidades de manera automática incluso sin que el conductor sea consciente de lo que está pasando. Sirva como ejemplo que el vehículo conectado podría contactar directamente con el concesionario o punto de revisión del vehículo algunas semanas antes de que el conductor sea consciente de ello y es la tienda de revisión y reparación la que va a llamar al cliente para realizar el mantenimiento del coche. Esto nos lleva a coches más inteligentes, antesala de los vehículos autónomos, que además de conducir solos van a gestionar sus propias necesidades sin la contribución del conductor.

Todos estos avances tecnológicos han permitido a las empresas del mundo de la movilidad gestionar, capturar y procesar gran cantidad de datos. Las nuevas tecnologías han permitido nuevas formas más rápidas y económicas de tratar estos datos de manera masiva. La captura y procesamiento de los datos de los vehículos también está revolucionando la industria de la automoción y por extensión, todos los sectores que la rodean. El mundo de las compañías aseguradoras de autos no es una excepción y gracias a la recogida y procesamiento de datos hoy en día se puede calcular, por ejemplo, el riesgo apriorístico de tener un accidente de un determinado conductor.

En este sentido, y gracias a todo el conjunto de datos que hoy en día se pueden captar, las compañías de seguros han desarrollado modelos de evaluación de riesgo de conductores basados en datos de movilidad de sus clientes [15]. Esos datos, convenientemente tratados, pueden permitirnos analizar los factores de riesgo de cualquier conductor en tiempo real y con ello las aseguradoras de automóviles pueden ofrecer al mercado nuevos productos con mejores precios basados en el comportamiento del conductor [16]. Reducir los factores de riesgo podrían suponer mejorar el margen de las compañías aseguradoras y así se podría conseguir un mejor precio de esas pólizas de seguros para todos los usuarios además de traducirse en una mayor seguridad para el conductor [17]. Este análisis es parte del trabajo que se ha realizado también en esta tesis, midiendo el impacto que en términos de tarifa de seguro puede tener el comportamiento de los datos recopilados de un conductor. Además, esta tesis da un paso más y en lugar de valorar y clasificar a los conductores en base a su frecuencia y tipo de uso del auto, lo hace en base a la localización de los conductores lo que nos lleva a desarrollar un modelo de estilo de vida del conductor y en base a eso un clasificador de riesgo para el mundo asegurador.

1.1.3 Organización de la tesis según las contribuciones científico técnicas realizadas

La tesis que aquí se presenta se divide en 6 capítulos. Además de la introducción, la tesis se apoya en la contribución de 3 artículos científicos publicados lo que permite ofrecer una visión más completa de las distintas oportunidades observadas a través de estos documentos.

Los artículos científicos que forman parte del estado del arte de la presente tesis se centran en una línea de investigación con 3 perspectivas de análisis distintas. La premisa de partida reside en que la tecnología puede tener un impacto en las personas y más concretamente en los conductores. Esos impactos generan datos que pueden ser recogidos, tratados y analizados. Esta tesis se centra en analizar todos estos impactos, desde tres puntos de vista distintos:

1) El primer artículo, capítulo 3, se centra *en analizar el impacto de diferentes tipos de servicios y cómo estos pueden ayudar en el proceso de decisión de los conductores*. Además, examinamos la influencia de las distintas técnicas de persuasión de la tecnología en la conducción. Este artículo concluye con los principios de persuasión que más aplican en el mundo de la conducción en reducir los costes de conducción.

2) El segundo artículo, capítulo 4, da un paso más y nos propone un *análisis de los factores que más van a afectar al gasto alrededor del vehículo*. Este trabajo se realizó a través de un panel de expertos utilizando la metodología Delphi. Los resultados de este análisis se contrastaron con una muestra real de conductores, realizando una encuesta para ayudar a determinar los factores que realmente más afectan a los gastos del auto.

3) El tercer artículo, capítulo 5, se centra en la *creación de un modelo nuevo, a través de modelos supervisados de machine learning e Inteligencia Artificial para estimar el perfil de riesgo en función de los distintos puntos visitados por un conductor*. De esta manera, el autor propone una metodología de evaluación de conductores nueva y no evaluada hasta la fecha.

1.2 Hipótesis y objetivos de la investigación

La misión de esta tesis es analizar la reacción de los conductores ante determinados estímulos tecnológicos, en distintos escenarios de movilidad, determinando así el grado de utilización de la tecnología para conseguir ahorros en el ámbito del vehículo privado.

Para ser más precisos, nuestros objetivos específicos son:

1. OE1. Recoger datos del vehículo, incorporando principios de diseño persuasivo examinando la influencia que estos principios tienen en los conductores y en el rendimiento de la conducción;
2. OE2. Analizar el impacto, en términos de ahorro, de la tecnología embarcada en el vehículo;
3. OE3. Analizar el impacto de los diferentes servicios de conducción prestados en el ámbito del coche conectado y compararlos con vehículos convencionales;
4. OE4. Medir el impacto del tipo de conducción en función de los datos que se puedan obtener del vehículo;
5. OE5. Describir un clasificador para estimar el perfil de riesgo del seguro utilizando los datos de geolocalización del vehículo.

De acuerdo con los objetivos mencionados, identificamos una hipótesis general y algunas sub-hipótesis. Tras una revisión exhaustiva del estado del arte, el autor de esta tesis doctoral declara que no existen evidencias suficientes sobre el impacto de la tecnología en el ámbito de la movilidad desde el punto de vista del uso de las tecnologías para reducir los gastos alrededor del mantenimiento vehículo

Hipótesis General (HG): "*Si asociáramos un dispositivo inteligente a un coche convencional para transformarlo en un vehículo conectado, asegurando también la provisión de interfaces informativos y persuasivos, entonces reduciríamos los gastos asociados a tal vehículo e incrementaríamos su seguridad durante su vida útil".*

- **Sub-hipótesis:**

- SH1: Los conductores son receptivos a utilizar un dispositivo/artefacto inteligente para recoger información del coche que les pueda brindar beneficios en lugar de otros métodos tradicionales;
- SH2: Los principios de persuasión que más se adecúan a la tecnología embarcada en el coche son los que más relación tienen con la reducción de los gastos asociados del vehículo;
- SH3: Los vehículos conectados reducen los gastos en su movilidad respecto a los vehículos convencionales no conectados;
- SH4: El patrón de movilidad de un conductor permite determinar su perfil de riesgo siniestral y por tanto permite optimizar el precio que una aseguradora ofrece a su cliente.

1.3 Metodología

En este trabajo se ha utilizado una combinación de enfoques y metodologías procedentes de las humanidades, las ciencias sociales, los estudios urbanos y los estudios de la información y las comunicaciones, centrándose en los métodos de investigación cuantitativa principalmente. Como toda investigación, los métodos listados a continuación se han aplicado tras revisar la literatura científica para cada toma de decisión en un ejercicio iterativo por fases en el que se identifica el problema, se buscan diferentes soluciones para abordarlo, se selecciona la que se considera más idónea, para sacar resultados iniciales, compararlos con la referencia y publicar los resultados obtenidos tal y como puede observarse en la figura 3.

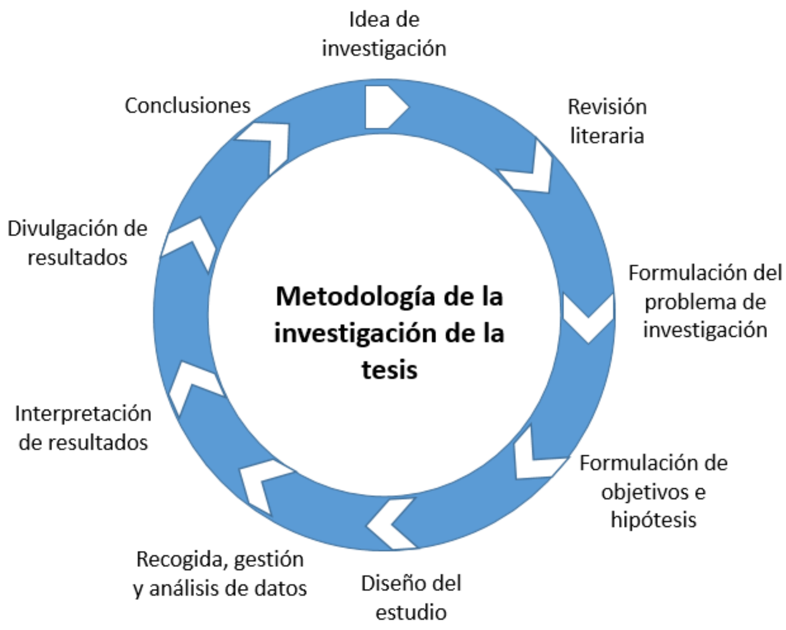

FIGURA 3. METODOLOGÍA DE INVESTIGACIÓN DE LA TESIS

Además, y para facilitar la lectura incluimos una tabla que correlaciona las metodologías de investigación que se han utilizado en esta tesis:

Tabla 1: Metodologías utilizadas en la Tesis

	Paper I	Paper II	Paper III
Análisis cuantitativos	✓	✓	✓
Sistema de recogida de datos	✓	✓	✓
Análisis y procesamiento de datos	✓	✓	✓
Metodo Delphi		✓	
Análisis estadísticos			✓
Modelos de aprendizaje supervisados			✓
Análisis de componentes principales			✓
Análisis de clasificadores			✓

1. En los tres artículos científicos indexados que forman parte de esta tesis, se han utilizado unos dispositivos para recoger datos de los vehículos y su movilidad, tales como la información del GPS, acelerómetro, giróscopo, velocidad y el resto de las variables relacionadas con los movimientos de un vehículo en un mapa, tal y como se puede observar en la Figura 4.

FIGURA 4. DISPOSITIVO IOT EMPLEADO PARA LA ELABORACIÓN DE ESTA TESIS

Este dispositivo forma parte de la solución de vehículo conectado de una compañía tecnológica llamada Grupo Next (www.gruponext.es). Esta empresa nos facilitó dispositivos, muestras de conductores y la tecnología necesaria para poder recoger datos y elaborar nuestro trabajo. Este dispositivo, por tanto, ha inspirado el trabajo científico que aquí se presenta. Esta tecnología viene siendo utilizada en distintos mercados alrededor del mundo para dotar al vehículo de una fuente de acceso a los datos para poder ofrecer distintos servicios digitales a los conductores.

2. En los 3 artículos científicos de esta tesis por compendio, se ha utilizado una metodología de análisis cuantitativos a través de encuestas para determinar la idoneidad de la utilización de un dispositivo de información en un vehículo para evaluar la conducta de los conductores.

3. El método Delphi [18] se utilizó en uno de los artículos para poder identificar qué características podrían tener más impacto en la gestión de la economía alrededor del vehículo conectado.

4. Diferentes análisis estadísticos [19] fueron efectuados para determinar comparación de muestras de encuestas de conductores con vehículos conectados y no conectados en el tercer artículo.

5. Un estudio basado en Modelos de aprendizaje supervisados [20] (inteligencia artificial) fue utilizado en el último artículo. La Categorización estuvo basada en los Puntos de Interés. A su vez dichos modelos están basados en el análisis del estilo de vida de los conductores, es decir, cuáles son los Puntos de Interés que visita un conductor. Este trabajo se realizó en el tercer artículo científico.

6. Análisis de componentes principales [21]. Es una técnica para la reducción de dimensionalidad en modelos supervisados (Inteligencia Artificial). Esta técnica se aplica a las variables con el fin de obtener un conjunto de datos más reducido para entrenar los modelos de datos supervisados. Fue usado, de nuevo, en el tercer artículo.

7. Desarrollo de un modelo de análisis de clasificadores [22] para determinar cuál es el que más aplica en la investigación propuesta, en el artículo 3

8. Sistemas de análisis y procesamiento masivo de datos para el procesamiento de información de localización fue utilizado en artículo 3.

La metodología se desarrolla en detalle en cada una de las publicaciones que componen esta disertación.

1.4 Estructura de la Tesis

Esta tesis está dividida en seis capítulos. Además de la introducción y las conclusiones, se incluyen tres artículos científicos publicados en revistas indexadas, lo que hace que esta tesis sea por compendio. Cada uno de estos capítulos contiene una breve introducción y un análisis de la motivación, la relevancia, el contexto, la contribución principal y los detalles de publicación del artículo correspondiente.

El capítulo 2 revisa el estado del arte, donde se analizan otros trabajos e investigaciones similares que se han ejecutado hasta la fecha, comparadas con nuestras aportaciones y conclusiones.

En los siguientes capítulos, se incluyen las publicaciones indexadas que forman parte de la investigación de esta tesis.

A modo de resumen, el capítulo 3 nos propone un estudio y análisis del comportamiento de los conductores de vehículos utilizando un Artefacto tecnológico que se instala en los vehículos. Este sistema hardware se utilizó para analizar los distintos modelos de persuasión, lo cual nos permitió identificar cuál era el más útil o apropiado para los conductores.

El capítulo 4, supuso un siguiente paso en la investigación, ya que analizó los factores que afectan al gasto de los conductores de vehículos conectados. Esta publicación se refiere primero a un análisis de determinantes mediante uso de la metodología Delphi y posteriormente se completa con sendas encuestas a usuarios de vehículos conectados y no conectados para analizar la diferencia de los gastos entre ambas muestras.

Una vez conocemos el impacto de la tecnología en el comportamiento y el impacto de los factores que afectan al gasto de los conductores, el capítulo 5 analiza un caso de uso; a partir de los datos de geolocalización de un coche, establece los puntos de interés y elabora un perfil de siniestralidad para el mundo asegurador. Este artículo analiza cómo las herramientas que proporciona la tecnología actual al mundo de las compañías de seguros, pueden ayudar a realizar una mejor evaluación de sus clientes basado en la gran cantidad de información interconectada y procesada.

Finalmente, el capítulo 6 proporciona las conclusiones finales del presente trabajo. Estas conclusiones incluyen las contribuciones a la tesis, la validación de las hipótesis, así como una aproximación a los trabajos futuros.

CAPITULO 2: Estado del arte

Este capítulo recoge y revisa el estado del arte relacionado a la investigación realizada. Para facilitar su lectura, vamos a dividir este capítulo en 3 secciones. La primera de las secciones analiza el estado del arte sobre sistemas tecnológicos basados en los principios de persuasión, el segundo analiza las investigaciones e información relevante sobre las variables que afectan al consumo en el mantenimiento del vehículo y como las tecnologías pueden ayudar a reducir estos consumos y la tercera sección revisa la literatura existente sobre la tipología de análisis de riesgos para perfeccionar el precio del seguro de autos.

Este enfoque puede verse en la figura 5:

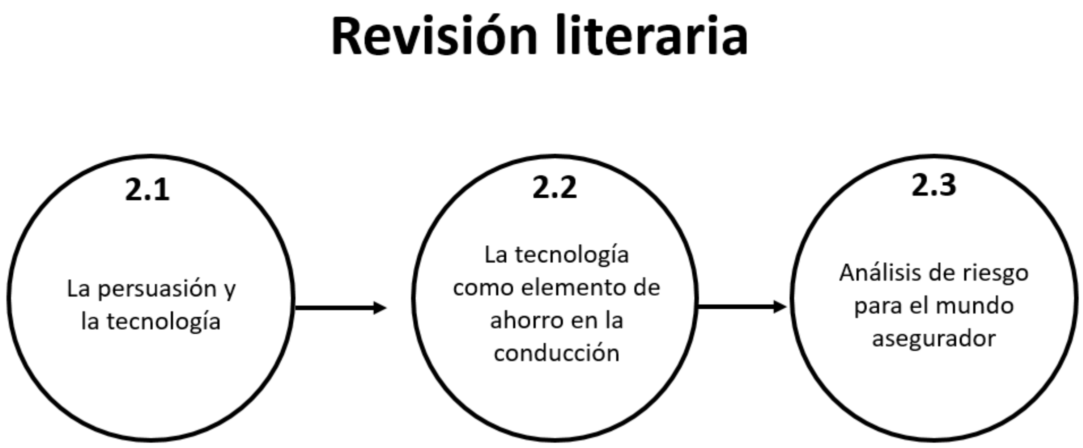

FIGURA 5. MODELO DE REVISIÓN LITERARIA

2.1 La persuasión y la tecnología

Para poder analizar y profundizar sobre los sistemas tecnológicos basados en los principios de persuasión, debemos analizar todas las herramientas que se han creado. Para ello, la revisión literaria se realizó en base a los siguientes puntos:

(i) Principios de Diseño Persuasivo para comprender el marco general
(ii) Los principios de diseño persuasivo que aplican a esta tesis
(iii) La tecnología que puede ayudar a persuadir o influir en un conductor
(iv) Nivel de aceptación de los conductores respecto a las diferentes tecnologías.

En este último punto, la idea era estudiar las diferentes tecnologías existentes para persuadir o influir en las personas y más concretamente, si era posible, entender la relación que existía con el conductor. En resumen, este apartado sintetiza la base teórica del estudio y revisa el impacto que varios sistemas de asistencia a la conducción tienen en las personas y cómo estos pueden ser útiles en el proceso de toma de decisiones del conductor cuando se trata de reducir el gasto del automóvil alrededor de su vehículo.

Según De Steno et al. [23] los intentos de persuasión tecnológica en las personas son más exitosos cuando el comportamiento liberado por el mensaje está en armonía con el estado emocional del receptor. Por tanto, las emociones son relevantes ya que influyen en las personas [24]. El propósito principal de poder evaluar la interacción que realiza un conductor es observar su propio comportamiento.

Por consiguiente, en esta sección se abordan las investigaciones basadas en la persuasión. La investigación en psicología ha estudiado durante mucho tiempo la persuasión para entender e influir en el cambio de comportamiento de las personas [19, 20].

Los comportamientos de las personas han sido ampliamente estudiados en términos de la influencia que el uso de la tecnología puede tener sobre ellos [27], 22]. Sin embargo, tras revisar el estado de la cuestión usando medios bibliográficos y revisión de la literatura, no se han estudiado en profundidad los ahorros o gastos que puede realizar una persona a partir de la influencia o persuasión de una máquina en tiempo real y durante la conducción.

Según Oinas-Kukkonen & Harjumaa [29], existen 4 tipos de categorías en los que se pueden ordenar los 28 principios de persuasión. Además, a estas 4 categorías Fogg [30] (p. 187) introduce "el Factor Kairos". Este factor establece que gracias a un dispositivo móvil, tenemos la capacidad de poder mostrar un mensaje, en el momento adecuado, para tratar así de aumentar el potencial de persuasión [30] (p. 188).

Además de la persuasión, elemento fundamental, tal y como estamos viendo, también debemos revisar las interacciones hombre-máquina de forma que eso nos ayude a entender la adaptación que la tecnología debe tener. Duncan et al. [31] comentan que si una persona tiene un sistema de ayuda a la conducción, se familiarizará más con ese sistema (tecnológico) que hay detrás y por tanto tendrá una mejor opinión de ella. En otras palabras, las personas se adaptan a la tecnología e idealmente debemos adaptar la tecnología a las personas.

Tabla 2: Resumen de la revisión literaria de los elementos tecnológicos que pueden influir en personas

Acronym	Description	Notification System	Designed to	Technology
PDP	Persuasive Design Principles	Theory	Influence human behaviour	General
HCI	Computer Human Interaction	Multimodal notification interface	Driving safe, comfortable and efficient	Embedded into the car
ADAS	Advanced Driver Assistance System	Multimodal notification interface	Safety and Efficiency Driving	Embedded into the car
ITS	Intelligent Transportation Systems	Road panel notifications	Improve drive safety	Road panels
MIS	Management Information System	Road panel notifications	Information (places, petrol stations,…)	Road panels
TAM	Technological Acceptance Model	Theory	Technology use acceptance	General
TAM2	Technological Acceptance Model 2	Theory	Technology use acceptance	General
TAM3	Technological Acceptance Model 3	Theory	Technology use acceptance	General
TRA	Theory of Reasoned Action	Theory. TAM predecessor	Technology use acceptance	General
TRAM	Technological Readiness Acceptance Model	TAM evolution	Technology use acceptance	General
DAS	Driver Artefact System	Based on OBD-II device	Real-time recommendations	OBD + APP

En la Tabla 2 se presenta un resumen de la revisión literaria de diferentes elementos tecnológicos que pueden ayudar, permitir o influir en la persuasión del conductor.

A la izquierda de la tabla se titulan las siglas con los diferentes sistemas analizados. En la siguiente columna se indica el nombre completo de la sigla. La columna siguiente, denominada "Notification System", recoge la forma en que actúa la tecnología, es decir, la modalidad de interacción. La columna "Designed to" hace referencia a la utilidad que esa tecnología pretende cubrir o para lo que fue diseñada. La última columna nos ofrece información sobre la forma en la que la información, a través de distintos medios tecnológicos, llega al usuario.

Este esquema se asemeja al propuesto por Paraschivoiu et al. [32] quienes presentaron una revisión de sistema persuasivo en vehículos basados en el diseño de Interfaz de Persuasión en el contexto del entorno automotriz. Su marco integra intenciones (los objetivos), señales (la forma de persuadir), principios persuasivos y opciones de diseño (sistema de notificación y tecnología utilizada) para la tratar de persuadir a un conductor.

En la Tabla 2 se analizan once tipos de elementos tecnológicos que pueden influir en las personas y, más concretamente, los factores sobre los que se apoya esa influencia.
Además, se han propuesto y abordado diferentes sistemas y tecnologías relacionadas con la interacción con los conductores, dentro y fuera del coche. En este contexto, se ha revisado la denominada "Computer Human Interaction (HCI)" como una interfaz de notificación multimodal diseñada para facilitar la conducción [33].
También se ha incluido el Sistema Avanzado de Asistencia al Conductor (ADAS por su acrónimo en inglés) por ser un sistema de tecnología para interfaces de notificación de seguridad en tiempo real durante la conducción [34].

En cuanto a analizar la influencia de los paneles de notificación de la infraestructura vial, los paneles de la carretera, se analizaron los denominados "Sistemas Inteligentes de Transporte (ITS, por sus siglas en inglés)". Este sistema se corresponde con un conjunto de soluciones que están diseñados para mejorar la seguridad y la comodidad de los conductores [35].

La literatura referente a incentivos a la persona con el objetivo de lograr beneficios económicos también fue incluida en este análisis. En este campo se ha analizado los llamados "Sistemas de Información de Gestión (MIS, por sus siglas en inglés)". Esta tecnología está orientada a provocar cambios en el comportamiento del conductor con respecto a un patrón habitual de consumo, en respuesta a señales de precios o incentivos en las carreteras [44].

También se consideró la aceptación de nuevas tecnologías a través del TAM (Modelo de Aceptación Tecnológica). TAM es una teoría de los sistemas de información que modela cómo los usuarios aceptan y usan una tecnología [30, 31]. Este modelo se basa en que se puede inferir mediante el análisis si una sociedad es más proclive a incorporar novedades o, por el contrario, es conservadora.

Por otro lado se analizó la Teoría de la Acción Razonada (TRA) [38] la tecnología antecesora de TAM [39]. Se han hecho intentos para desarrollar otras derivadas de este modelo, tales como TAM 2; TAM 3, y el denominado "Modelo de preparación y aceptación de tecnología (TRAM)" [40], [41]]. Bombilier Chaumont [42] describe el proceso de la aceptación de la tecnología como una trayectoria que va desde el inicio del diseño de un sistema hasta su implementación.

Finalmente también se ha estudiado la aceptación asociada al uso de la evaluación de un artefacto de TI en tiempo real [43]. Por lo tanto, este análisis ha tratado de aportar algo de comprensión en cómo sistema de Tecnologías de la Información (TI) puede integrarse o no en la vida de los conductores, lo que podría influir en modificar o transformar la organización de sus viajes, los servicios de automóviles o el mantenimiento del vehículo.

En la parte inferior de la tabla se ha incluido lo que hemos denominado DAS (Driver Artefact System) que es el sistema analizado por el autor de esta tesis. El sistema DAS es una tecnología que consta de un dispositivo conectado al vehículo y una APP para el conductor y que en función de la ontología de este y el análisis de sus patrones de conducción ofrecen soluciones ad-hoc y en tiempo real a las necesidades que surjan en la conducción.

Hasta ahora, en esta revisión se observa que hay muchos elementos tecnológicos que están diseñados para intentar influir en el comportamiento de los conductores. La mayoría de ellos se diseñaron para hacer que la tecnología sea más accesible, más comprensible e incluso más simple para los conductores. Algunos de ellos, en materia de movilidad, intentan ayudar al conductor a ser más eficiente y seguro en la carretera. Sin embargo, según lo revisado hasta la fecha, no existe ninguna investigación que emplee Tecnología de la Información y de las Comunicaciones (TIC) para ayudar e influir en los conductores para que ahorren tiempo y dinero en sus actividades de movilidad de su día a día. Más en concreto, no se ha encontrado evidencia a lo largo de la revisión de la literatura sobre qué tipo de principios de persuasión aplicarían mejor a cada conductor en diferentes contextos. En esta línea de analizar los ahorros, profundiza la siguiente sección. Uno de los objetivos de esta tesis está en analizar la capacidad de ahorro que puede tener un conductor a través de estímulos generados por tecnología. Es lo que se analiza en la siguiente sección.

2.2 La tecnología como elemento de ahorro en la conducción

En el punto anterior hemos analizado la literatura que hacía referencia a los elementos de persuasión al conductor, siempre desde el prisma de tratar de ahorrar dinero en esa llamada movilidad personal. En esta sección 2.2 vamos a avanzar en la dirección de revisar las variables que podrían afectar el consumo de los vehículos poniendo el acento en las tecnologías que podrían desempeñar un papel activo en la reducción de los gastos de la movilidad del vehículo. Para llevar a cabo este trabajo, se ha analizado la literatura desde 3 puntos de vista distintos:

2.2.1 Los servicios del coche conectado
2.2.2 Las variables que afectan a los gastos del vehículo
2.2.3 El papel de la tecnología en la reducción de precios y el impacto medioambiental

2.2.1 Servicios de coche conectado

El campo del automóvil conectado es parte de la evolución de la movilidad. En esta línea, la introducción del Ordenador Personal (PC) en el ámbito del uso doméstico podría considerarse el primer paso y, posteriormente, la revolución de Internet podría ser considerado el segundo. El mundo actual está hiper-conectado y el automóvil no es una excepción [44]. Como indica Swan [44] , la mayor limitación de un coche conectado es la gestión de la privacidad de los datos. En este contexto, todas esas enormes cantidades de datos que genera un vehículo (50 Mb al día) podrían usarse para generar diferentes modelos de negocios [45].

Todos los datos recopilados y procesados que genera el automóvil pueden ser muy valiosos si se comparten adecuadamente [46]. Gracias a los datos, se podrían generar muchos servicios alrededor del automóvil [47].

La información de los coches conectados pueden verse también como un sistema que puede ser compartido con las autoridades locales para enviar alertas en ciertos escenarios, tales como posibles accidentes o averías en los automóviles que tengan impacto en el tráfico del día [48]. Dhall & Solanki [48] indican que el sistema del vehículo conectado puede utilizarse para desarrollar una conexión V2X (Vehicle-to-Everything), lo que permite monitorear la movilidad de nuestras ciudades, ver las condiciones ambientales en tiempo real y desplegar diferentes servicios en torno al ecosistema de movilidad creado.

En promedio, el 20 % de los compradores de automóviles nuevos afirman que estarían dispuestos a cambiar a una marca de automóvil diferente para obtener mejores servicios de vehículos conectados [49]. Mikusz y Herter definen los servicios de automóviles como servicios basados en la conexión inteligente del vehículo con su entorno, como la infraestructura de transporte que los rodea. Sin embargo, no debemos olvidar que todos estos servicios deben ser relevantes para el usuario final. Hebeler y Hofmann [50] argumentan que muchos servicios de los coches conectados se implementan sin valor monetario para los propios conductores.

El "Coche conectado" es una terminología que a menudo se asocia con aplicaciones para gestionar mejor el mantenimiento y los servicios del automóvil, como el cambio de neumáticos y el mantenimiento del automóvil [48]. Möller y Has [51] han estudiado en profundidad la evolución del coche conectado, teniendo en cuenta los niveles de madurez de la tecnología, los factores que lo impulsan y los modelos de negocio que generan. Podemos afirmar, por tanto, que existe mucha literatura referente al impacto del vehículo conectado, pero al mismo tiempo podemos argumentar que no se refiere al impacto económico si lo comparamos, por ejemplo, con un vehículo convencional.

2.2.2 Variables que afectan a los gastos de los vehículos

Pocos trabajos académicos anteriores se han interesado en explorar esta área. Hay muchas variables que pueden desempeñar un papel importante en los gastos de los automóviles [52].

El consumo de combustible, representando un 50% de los gastos anuales alrededor del auto, siendo por tanto uno de los gastos más relevantes, ha sido ampliamente analizado. Parry [53], por ejemplo, indica que se puede lograr una reducción del 9,1 % en el consumo de combustible gracias a la tecnología integrada en el vehículo. Señala que, en función de menores niveles de conducción, menores tarifas de seguros (por la menor exposición al riesgo) y también menores gastos de combustible. Por lo tanto, las TIC's pueden funcionar como un elemento de persuasión, transformando a los conductores en personas más informadas y, por lo tanto, sensibles a gastar de manera más inteligente. El gasto hay que hacerlo, pero se puede racionalizar y se puede ahorrar.

Con respecto a lo que se puede considerar como gastos de automóvil y cómo estos varían, Kim, Hwangbo y Kim [54] indicaron que los gastos pueden variar según el tipo de conducción, las circunstancias de conducción, el tipo de automóvil, la velocidad con la que se conduce, y otros factores relacionados con el uso del automóvil. Hay otros estudios [55] que muestran que el 44,33% de los compradores de vehículos eléctricos o híbridos también son compradores de paneles solares domésticos. Un total de 12,67% indica que aún no ha comprado paneles solares, pero planea comprarlos pronto. Si se agregan ambos porcentajes, se puede deducir que el 57% de las personas que conducen un vehículo sostenible (en términos medioambientales) también lo son en otras actividades de su vida cotidiana. Este es un factor relevante ya que la tecnología puede ayudar a condicionar la actitud de las personas, como veíamos en la sección anterior y las personas que adoptan una actitud como patrón de comportamiento evolucionan de acuerdo a ese patrón [56].

2.2.3 El papel de la tecnología en la reducción de precios y el impacto ambiental

La literatura existente se ha centrado principalmente en medir algunos parámetros del automóvil con el fin de controlar su actividad (usos, desgastes, consumos,…) [57]. Algunos autores se han centrado en el control del mantenimiento de los automóviles mediante sistemas de radiofrecuencia instalados en las carreteras. La capacidad de revisar un auto de forma remota a través de la tecnología (por ejemplo, cambio de aceite, cambio de llantas o cambio de pastillas de freno) es parte de lo que se busca en esta revisión literaria. Según los fabricantes de automóviles, gestionar un vehículo a tiempo siempre repercute en la reducción de costes directos e indirectos. De esta forma, Lin et al. [40] mencionaron en su investigación que con la introducción de sistemas de diagnóstico remoto se puede controlar las flotas y prepararse ante las inversiones en futuras reparaciones.

Hay una tendencia adicional y actual que analiza el impacto de vender movilidad en lugar de automóviles. Según un análisis empírico de Firnkorn y Müller [58], los vehículos privados se han reducido y eso tiene un impacto muy importante en todo el sector del mundo del automóvil. Esta teoría confirma que se observa un vehículo como generador de gasto y existen, según el mismo estudio, algunos usuarios que quieren pagar sólo por "el uso" o sus "necesidades" de movilidad. Otros estudios han reflexionado sobre el vínculo entre el uso de la tecnología y la energía [59] y entre la gestión de la eficiencia energética mediante la tecnología y la gamificación [60]. Hasta el momento no se ha encontrado evidencia escrita en el ámbito de uso del automóvil y gestión del ahorro como tal.

En conclusión, podemos afirmar que, habiendo revisado el estado del arte en este campo, esta tesis permite llenar un vacío en la literatura sobre la movilidad con respecto a permitir identificar qué variables son más importantes en relación con los gastos de los vehículos. Uno de los sectores más relevantes que analizan permanentemente el comportamiento de los conductores para tratar de que conduzcan mejor y eso tenga impacto en su economía, son las compañías aseguradoras.

2.3 Caso de uso: análisis de riesgo para el mundo asegurador

Según apuntábamos en el párrafo anterior, en los últimos años, algunas aseguradoras se han interesado en mejorar sus cuentas de resultados a través de incorporar nuevas variables que les permitan anticipar un posible riesgo y por tanto una indemnización. En esta línea, un vehículo mejor mantenido es un vehículo con menos riesgo y seguramente con un perfil mejor de conducción.

Las aseguradoras ya están aplicando modelos de datos a través de los datos que recogen de los vehículos. Esta tecnología les ha permitido capturar datos como velocidad, número de kilómetros recorridos, tipo de vía utilizada, frecuencia, horarios, etc. Con estos nuevos tipos de datos, incorporados a sus variables tradicionales, se están construyendo modelos de riesgo a medida del individuo [61]. Estos nuevos modelos que están utilizando las aseguradoras, se han extendido principalmente en Europa y EE.UU. Con estos antecedentes en mente, vamos a analizar la literatura existente sobre el cálculo de las variables de riesgo dentro del mundo de los seguros de automóviles. Más concretamente, vamos a analizar la literatura sobre "Driving Behavior (DB)" y los llamados "Usage Based Insurance (UBI)".

Estos modelos que acabamos de citar se han desarrollado en el contexto del análisis del comportamiento de los conductores bajo el modelo conocido como Pay As You Drive (PAYD).

Estos modelos de comportamiento de los conductores suelen estar respaldados por datos del vehículo basados en la conducción, incluida la velocidad del vehículo, las Revoluciones Por Minuto (RPM) del motor, la posición del acelerador, la carga del motor y muchos otros parámetros [62].

Las compañías de seguros están comenzando a introducir modelos de descuento basados en el uso y el seguimiento del tipo de uso del automóvil [63]. Sin embargo, no se ha identificado en la literatura revisada trabajos relacionados con un enfoque que vincule el riesgo de un conductor en función de los puntos de interés que visita y la frecuencia con la que los visita, como se describe el artículo recogido en el capítulo 5.

En el mundo de los seguros, el uso de la tecnología está directamente relacionado con el factor de reducción de accidentes [64]. Este uso de la tecnología no siempre ha sido enfatizado de la misma manera. De este modo, esta revisión de la literatura analiza y estudia la mayoría de los modelos de análisis de riesgos. Hemos visto que la mayoría se centran en estudiar el elemento precio en función de dos variables: la frecuencia de uso del automóvil y la forma en que se utiliza el automóvil [65]. Esto allana el camino para considerar el perfilado de los usuarios en función de los puntos de ubicación visitados (geolocalización a través de GPS) y la frecuencia con la que estos puntos han sido visitados, que es una de las contribuciones de esta tesis.

Las aseguradoras, como hemos citado, ya incorporan, en algunos casos, la evaluación personalizada del riesgo del conductor a tarifas individualizadas de seguro [66]. Aun así, la mayoría de las compañías de seguros no tienen una forma de personalizar el riesgo y, por lo tanto, diseñan las primas de seguros con base en datos de riesgo a priori, sin considerar la información de conducción actual [53].

Hasta ahora carecían de tecnología embarcada en el vehículo o no le daban importancia. Sin embargo, la tecnología, como hemos visto, permite capturar datos del vehículo para caracterizar al conductor y así observar su comportamiento. En consecuencia, una aseguradora podrá adecuar la prima del seguro al riesgo previsto que presenta un conductor [67].

El enfoque seguido por esta investigación radica más en realizar un perfil del usuario a partir de la información extraída de los puntos que visita y la frecuencia con la que los visita, que en utilizar las variables típicas del análisis de riesgo (velocidad y frecuencia de paso del coche). usar).

Según Desyllas y Sako [68], PAYD es un método novedoso para determinar las primas de seguros en función de cuándo y cómo se conduce un automóvil. Las compañías de seguros podrían mejorar sus métodos de facturación alineando los riesgos individuales con los precios individuales [69].

La idea principal es que, en lugar de un precio fijo, los conductores podrían pagar una prima en función de su comportamiento de conducción, contextualizado como una puntuación de 0 a 10, siendo 0 el peor y 10 el mejor [70] el comportamiento de la conducción. Esta forma de disponer la fijación de precios de los seguros de autos es interesante y se puede llevar a cabo gracias a la explotación de los datos de localización de vehículos.

Tselentis, Yannis y Vlahogianni [71] argumentan que la instalación de programas UBI en las compañías de seguros no solo ayudaría a eliminar los riesgos de los conductores gracias a la conducción y el análisis de datos, sino que también puede motivar a los conductores a mejorar su comportamiento al volante a través de programas que permitan identificar áreas de mejora y mejores precios. Guillén et al [72] destacan que no solo es importante recordarle al conductor que cuanto menos conduce, menos probabilidad tiene de tener un accidente sino que también es igualmente importante enfatizar a los consumidores que mejorando su estilo de conducción podría llevar a la compañía de seguros a reducir las tarifas [65]. En este sentido, si los conductores no tienen accidentes y su comportamiento es el adecuado, según la aseguradora, los conductores deberían beneficiarse de reducciones en la prima de seguros.

En esta revisión literaria realizada se ha identificado que Italia es el país con mayor implementación de sistemas telemáticos en el campo de los seguros de automóviles. Una posible explicación es que el reglamento publicado en el año 2012 alentó este movimiento de sistemas telemáticos embarcados. De los 37 millones de automóviles que hay en el país, 4,8 millones ya están equipados con tales dispositivos, en comparación con los 3,3 millones de los estadounidenses o los 0,6 millones en el Reino Unido [73]. Según Porrini et al, existe una correlación directa entre el uso de dichos sistemas y la disminución de los accidentes automovilísticos y en la reducción del precio de las pólizas de seguros de automóviles. Este análisis nos introduce en el concepto de que el uso de la tecnología influye en la frecuencia de accidentes, pero no hace referencia alguna a los objetivos de muestro análisis que se centra en estudiar el riesgo de los conductores a partir de la caracterización de los puntos que visitan.

Carfora et al. [74] proponen la introducción de un modelo para analizar la identificación del comportamiento del conductor utilizando técnicas de aprendizaje automático no supervisado. Zhang et al. [75] Introducen el uso de algoritmos de regresión en los que algunos factores de riesgo de conducción se correlacionan con los accidentes, pero una vez más no analizan la información de geo-posición ni el análisis de la caracterización del usuario en función de la información de la frecuencia de los puntos visitados para obtener un modelo de perfil de riesgo del conductor.

Por lo tanto, se puede afirmar que el capítulo 5 de esta tesis cubre un claro hueco en la literatura revisada, respecto a la necesidad de introducir modelos de análisis y aplicación de seguros que varíen sus tarifas en función del comportamiento de los conductores.

CAPITULO 3: Mecanismos de persuasión para conductores de turismos enfocados a la toma de decisiones informada

3.1 Introducción al artículo científico y principales contribuciones

La tecnología juega un papel más relevante en nuestras vidas. Tal es así, que la tecnología puede ser uno de los componentes persuasivos más importantes para tomar decisiones cotidianas. La tecnología desempeña un papel relevante en su interacción con el ser humano pudiendo influir en su comportamiento y en la toma de decisiones. En este artículo científico se analiza el comportamiento de los conductores basado en la persuasión que a su vez tiene base en diferentes características o variables que influyen para que se tome una decisión específica o se adopte un comportamiento determinado con la ayuda de los sistemas y los artefactos de TI.

El presente artículo científico centra su estudio en el análisis de los principios de persuasión y cuál de ellos son más influyentes en conductores para la toma de decisiones al volante. Para ello, se añadirá un ranking con los 3 mejores principios y aquellos 3 que menos influyen.

El estudio que aquí se presenta trata de responder a las sub-hipótesis H1 y H2.

Recordamos ambas sub-hipótesis:

- SH1: Los conductores son receptivos utilizar un dispositivo/artefacto para recoger información del coche que les pueda brindar beneficios.
- SH2: Los principios de persuasión que más encajan en la tecnología embarcada son los que más relación tienen con la reducción de los gastos del vehículo.

La metodología que se aplicó en este artículo fue la siguiente sigue la metodología circular presentada en el primer capítulo, pero de forma específica se resume en las siguientes fases:

- Se elaboraron encuestas en donde se preguntó a los participantes sobre la influencia de la tecnología en su toma de decisiones.
- Todos los usuarios a los que se encuestó eran usuarios de vehículos conectados, luego estaban familiarizados con el uso de la tecnología.
- En la encuesta se pidió a los conductores de turismos que autoevaluaran las estrategias derivadas de los principios de persuasión que se aplican a esta investigación.

El estudio concluye su trabajo indicando cuales son los principios de persuasión más relevantes para los conductores, siendo el "self-monitoring" el más importante, el "tailoring, personalization and Kairos" el segundo y "reminders and suggestions" los terceros. Los principios de persuasión menos relevantes son aquellos relacionados con el "social learning & recognition", "linking & expertise" y "simulation, praise & rewards".

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3.2 Analysis of Driver's Reaction Behavior Using a Persuasion-based IT Artefact

Article

Analysis of Driver's Reaction Behavior Using a Persuasion-based IT Artefact

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Abstract: The use of interactive technology to change behaviour, which is commonly known as persuasive technology, nudge-based technology or gamification, is currently gaining attention in information systems research. It has been assessed in many applications contexts and the field of private mobility is not an exception, overall with the advent of self-driven cars. However, the reviewed body of research shows that when it comes to link persuasion-based systems and mobility, most of the approaches focus on engaging drivers to use the car in a safer way, leaving the cost-efficiency models while driving less explored. Therefore, this article focuses on the study of a persuasion-based IT artefact devised to make drivers more aware about car expenses (e.g., maintenance control, engine failures, enhance driving, etc.). Specifically, it aims to identify persuasive design principles of smart IT solution which are tailored for private cars. To this purpose, the results of a survey are presented where the respondents (N=301) were asked to rank different principles of persuasion to evaluate the most relevant for them to save time and money with their car. In essence, this paper contributes with a novel research that employs a persuasion-based IT artefact to help and influence drivers enhancing their management of cost related to car mobility in real-time. Implications of the proposed solution according to the responses of the survey are discussed in line with its implementation and adoption by car holders.

Keywords: Persuasive technologies, survey, mobility, motivation, behaviour, IT artefact.

1. Introduction

The growing technological development of the service sector and the globalization of markets, as well as the economy, are profoundly changing the organizations' structures. Such a change is evident by the progressive incorporation into companies of the current emerging technologies (e.g. advances in robotics, information technology, Internet of Things (IoT), telecommunications, and Artificial Intelligence) [1]. These are very helpful when it comes to integration, innovation, and autonomy of the process towards digitalization. From an engineering perspective, IT artefacts are usually designed to solve problems and, to a greater extent, produce a change in what is currently observable in order to generate a transformation in the behaviour of user. Indeed, this is not just the object of a passive observation, but a potential context of transformation or intervention [2].

The car is still one of the most used means of transportation on short distances [3]. According to a recent industry study of PWC [4], it is expected that current vehicles will have longer use by the year 2030 taking into account that 20% less vehicles will be sold. As a result, vehicles will have to withstand higher mileage contextualized on lower demand for new vehicles. If vehicles are going to have more use, the opportunity of gathering and analysing vehicle information remotely to manage cars' service needs appears as a business opportunity. This path opens a new research opportunity in terms of managing the car expenditure. Specifically, one of the elements that it needs to be analysed further is how the persuasion-based strategies through ICT, which have been applied with success in other contexts [5,6,7], affect to the car expenses. Indeed, Paraschivoiu et al. recently reported that persuasive applications targeting attitude and other domains apart from safety and eco-driving are almost entirely lacking [8]. The basis of this research is that cars are driven by people and those people could be persuaded in different manners [9]. Following this perspective, in this paper, the influence of persuasive technology on drivers is analysed. In addition, it aims to understand which persuasive principles are most applicable when they come to reduce the car mobility costs.

Continuous developments are being made to improve efficiency of travelling, reduce time consumption along with making it safer for the general public [10]. Various systems, tools and devices are designated to enhance not only mass communications but interpersonal communications [11]. The development of smartphones has helped users a lot in navigation terms, thereby making travelling much more reliable nowadays [12].

With these premises, there is no doubt that technology, through interactive systems, plays different roles in relation to human beings [13]. The interaction between the two can be presented in three ways; assigning the computer the role of tool, media, and social actor. The role of technology, as a social actor, is one of the most important persuasive components in the human-computer interaction model (HCI) [14]. Through this role, it is possible to influence people through positive feedback, helping to improve behaviour, and providing social support. In this context, "persuasive technology" refers to the study of the ability of technology to convince. Specifically, persuasive technology aims at changing, forming or removing behaviours by interacting with ICT-based systems. Fogg [9] coined the concept of "captology". Thus, the study of how computers can be used to persuade people to change their attitudes or behaviours. According to the scholar, "captology is an acronym derived from Computers as Persuasive Technologies". Oinas-Kukkonen and Harjumaa [15] (p. 486), defined a persuasive system as a "computerized software or information system designed to change attitudes or behaviour (or both) without using coercion or deception. Thus, building upon psychological research on human persuasion, it seems that a set of persuasive design principles can be embedded into IT artefacts to persuade users to engage in a target behaviour [16].

Based on the aforementioned reasoning, this paper analyses an existing IT artefact for the car. The artefact is an IT system connected to the car that provides relevant information that it can be used in different ways by the drivers (e.g., maintenance control, engine failures, enhance driving, etc.). As such, the IT artefact takes into account that the reaction of a driver in each context and moment can be influenced by many factors from the design of the IT artefact itself to the state in which the driver is [16]. In this context, Fogg [16] provided three determining elements to form, maintain or spark a behaviour: a) the motivation of the individual; b) the ability or ease of the actions proposed and c) the existence of triggers to bring the behaviour to occur. Hence, the design of the IT artefact draws upon this triad to form or enhance the drivers' eco-minded behaviour.

Taking the IT artefact as the basis, the goals of the article are manifold: (i) to analyse the impact of the different driving services and how they can be helpful in the driver decision making process (according to Duncan et al. [17] people that have a driver assistance system usually provide positive opinions about other systems such as navigation); (ii) to examine the influence of the persuasive technology on drivers and driving performance; (iii) to underpin which persuasive principles, among those provided in the existing literature, is most applicable to drivers when it comes to reducing the economic costs around the car.

The work is divided into four parts: the first part is the context of the research where the artefact is described. The second part is focused on reviewing the related literature and the context of the research. The origin, evolution, and importance of advances and innovations are discussed to review relevant literatures on car services and Persuasive Systems Design. The third part develops the methodology used in this article to try to identify if the technology works a relevant role into the drivers and which principles of persuasion are more relevant than others in influencing a driver. This is analysed at the results section (section 5). Section 6 concludes the article with some conclusions, recommendations and future work.

2. Context of the research: The Driver Artefact System (DAS)

As a departure point, an IT artefact available in the market is used. This artefact or DAS is provided by Grupo NEXT, a Spanish based company (www.gruponext.es). This company is focused on mobility data treatment and cost-efficiency driving models. The IT artefact selected has 3 main elements. The first element is (i) an OBD-II device (On Board Diagnostic) – an standard device connected into the vehicle, provided with a SIM card inside that transmits mobility information (e.g., location, speed, acceleration, braking, etc.) as well as information from the car's on-board computer (e.g., engine failures, engine temperature, maintenance needs, etc.). The second element (ii) is the Cloud-based platform, where mobility data is collected and the information is analysed. Finally (iii), the last element of the DAS is the end user mobile Application (App). With the App, the driver can browse his/her ongoing activity. Figure 1 illustrates the different components framing the IT artefact.

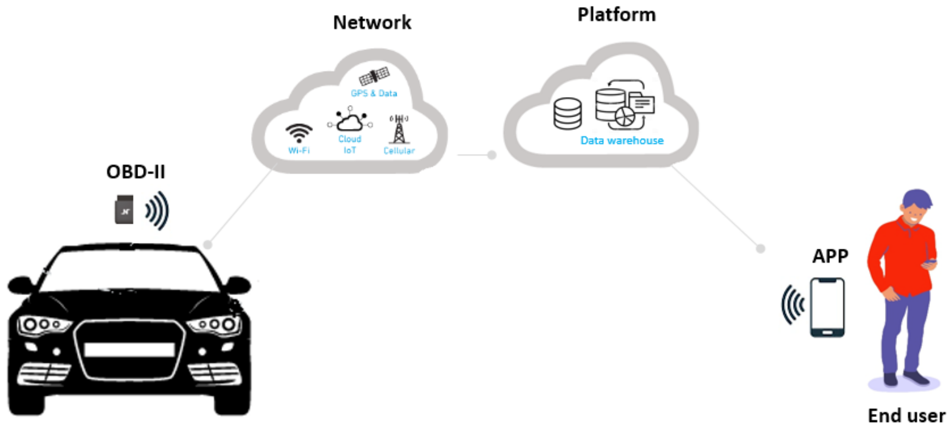


Figure 1. High level diagram of how the overall system

As mentioned in the previous paragraph, the artefact solution, as IT high level components visualization, is based on three clearly differentiated components (Figure 2). Those components are:

1. *The Platform* is a high-performance computer system, equipped with redundancy characteristics in all its critical elements, to allow the provision of the service without temporary interruptions. The platform also has interfaces with the information systems of the partners that provide real time services to drivers.
2. *The on board OBD device*, connected to the car port of each of the vehicles, reads data from the various sensors that the car has, to monitor the status of its various components, to send them to the platform for processing and exposure (ordered and managed). Generically, we can call these data the telemetry of the vehicle [18]. In addition, the device also incorporates a component to determine the geographical position in which the vehicle is using GPS technology. The most common technology of this type of devices supports is formed by a GPS module, a Global System for Mobile communications (GSM) communications system, an accelerometer, a gyroscope, a small microprocessor, the diagnostic process and a backup battery [19]. The data will be collected from the OBD device that is part of our IT artefact, which will allow us to know what is happening in the car and its mobility in real time and approach the user to propose a maintenance solution, when it is needed. DAS is a self-installing device which means that we will not have to use professional installers to board a device in a vehicle. This will simplify the testing. All these data is sent to a central computer to be analysed and processed normally thanks to the SIM allocated inside the artefact. The device contains a SIM card which, conveniently activated in the operator's 3G/4G

network, facilitates the periodic sending of car info. The device is complemented by the creation of a communications protocol. This communications protocol will allow us to send to a server the device info.

3. *A mobile application* allows the driver to manage the system/service himself, from its activation to its deactivation, including its configuration, the subscription of new value-added services and some data visualization. It also offers information about the saved money in real time, for car management purposes. This mobile application must be available for both Android terminals (versions equal to or greater than 4.4.x - KitKat) and iOS (versions equal to or greater than 9.0). The granularity of data collection as well as the frequency of sending them to the server can be handled manually by the operator of the artefact. According to Fogg [9], the App, as end user end point system, is a critical factor for the success of DAS.

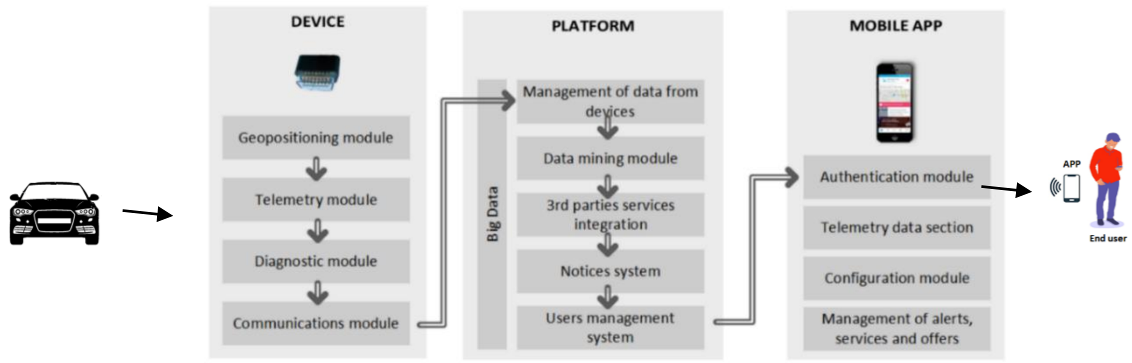


Figure 2. Technical IT artefact solution high level diagram

The APP information is organized in two categories: (i) car information (location, speed, car failures, engine check status, car movements, fuel, trip statistics, maintenance schedule, insurance schedule) and (ii) driver services through customized information and suggested promotions in real time (parking, restaurants, gyms, hotels, and so on). The first category refers to car events, naturally recorded during the vehicle mobility. The second category refers to real-time driver needs detection and offers in order to provide drivers with the best answers in terms of products and services. This second category is the target of this work, since the messages offered by the DAS in real-time might be much more efficient by using more appropriate persuasion strategies.

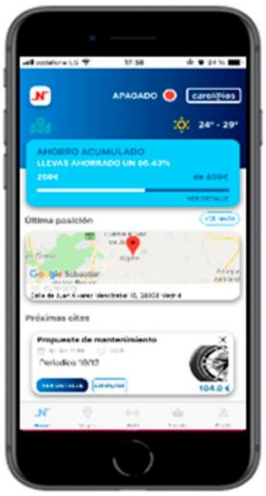
Figure 3 depicts some APP screenshots. The first one refers to the capacity of the system to send customized push messages to the end user's phone. The second screenshot offers a customized proposal (once the end user has shown interest in the push message by touching over it). The third image shows the alarms configuration, where the end user can activate or deactivate the information that she wants to receive. The fourth screenshot refers to car and driver personalized information. In the fifth one, the APP home screen can be seen, which includes some basic information and the savings achieved up to now. Finally, the last screenshot shows information related to trips: trip consumptions and trip details.

1. Customized push messages

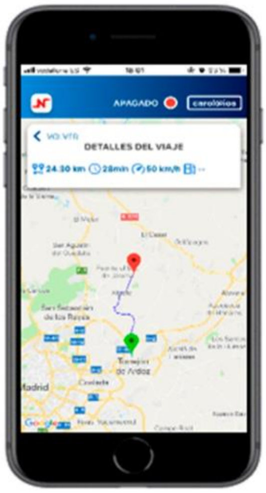
2. Suggested promotions

3. Alarm configurations

4. Customized driver information



5. Location and customized message



6. Trips and road informatio

Figure 3. Most relevant Application (APP) screen shots.

Those three components take into account technical aspects of efficient design. Like any element of automotive use, they must go through rigorous evaluation and testing methods to meet the required specifications [20].

Currently, cars are equipped with a large number of electronic sensors that fulfil several functions from receiving and issuing a signal to automation through the permanent exchange of data and information. Therefore, this explains the importance of this study and literature review of the existing research.

3. Background and literature review

This section reviews the existing literature on the design of effective systems based on persuasion to understand how an IT artefact can be devised to nudge drivers towards a more cost-sustainable driving. The context of sustainability is based on cost-efficiency and real-time services, depending on the car or driver needs. The impact of various driving assistance systems on humans is also reviewed and how they can be helpful in the driving decision-making process.

The revision of the body of knowledge starts with the Persuasion Design Principles. Figure 4 shows the literature review process. As can be observed, four categories of analysis were created: (i) Persuasive Design Principles to understand the framework; (ii) Persuasive Design Principles that apply to this research; (iii) Technology that could persuade or influence in a driver; and finally (iv), the acceptance level of drivers respecting to different technologies. The idea was to study the different existing technologies to persuade or influence people and more concretely, if it was possible, understand the driver's reaction. In essence, this section overviews the theoretical basis of the study and reviews the impact that various driving assistance systems have on humans and how they can be helpful in the driver decision-making process when it comes to reduce the car expenditure.

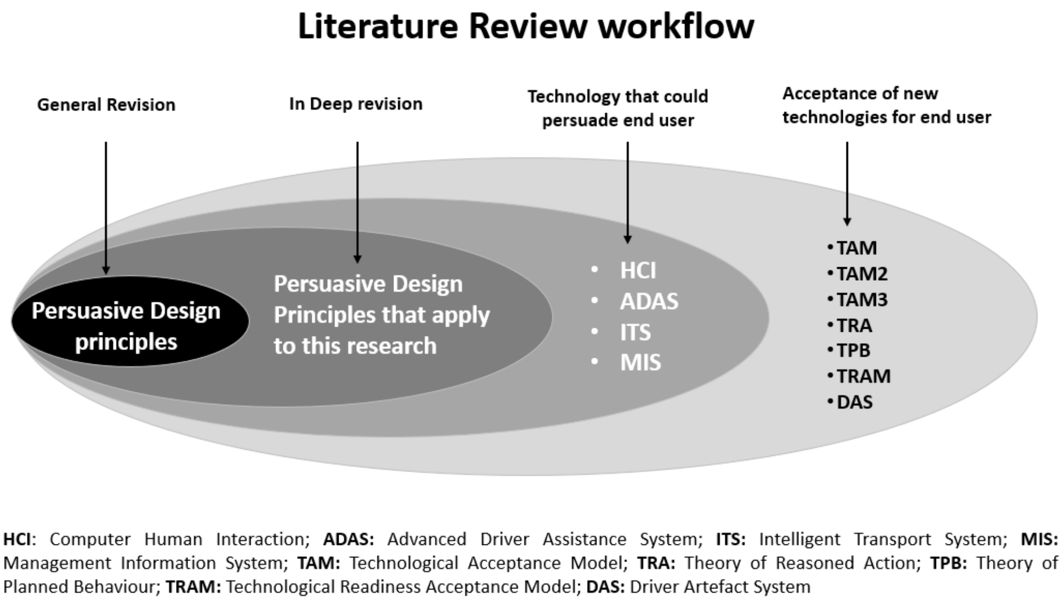


Figure 4. Literature Review workflow

According to De Steno et al. [21], persuasion attempts are more successful when the behaviour released by the message is in harmony with the emotional state of the recipient. The use of different emotions has different levels of influence [22]. The primary purpose of being able to evaluate the driver's interaction, with our IT artefact, is to observe the behaviour of the drivers, to produce appropriate responses in different situations [22].

Coming back to the theory behind this study, it is necessary to address the persuasion-based investigations. Research in psychology has long studied persuasion to foster behavioural change [19, 20, 21]. People´s behaviours have been studied in terms that the influence of the use of technology can have on them [10, 22]. However, they have not studied the impact, in terms of savings, that a person can have based on the influence or persuasion of a machine in real time. According to Oinas-Kukkonen & Harjumaa, [15] there are 4 types of principles categories, with 28 principles. Additionally, to these 4 persuasive categories, Fogg [16] (p. 187) introduces "the Kairos Factor". This factor states that: thanks to a mobile device (the IT artefact), we can present a message at the right moment to increase the potential to persuade [16] (p. 188).

Besides persuasion, human-machine interactions are also reviewed to understand the appropriateness of the technology to the driver and the interaction design that should be created. Duncan et al. [27] discussed that if a person has a driving aid system, she will become more familiar with the technology that is behind and therefore this person will have a better opinion of it. In other words, people adapt to technology, and ideally technology should adapt to people. In Table 1, a summary of the literary review of different technology elements that can help, allow or influence in the driver persuasion, is presented. At the left of the table, an acronym with the different systems analysed are entitled. The following column is related to the description, that is, the description is the full acronym name. The Notification System is the way that the technology acts to try to influence the driver (the interaction modality). The next column makes reference to what is intended to do. Thus, the goal (e.g., on influence on human behaviour, driving safe, driving efficiency, improve the driving, real-time recommendations, etc.). The next-to-last column captures the technology system in which the driver's behaviour is impacted. Finally, on the right the bibliography provides references to existing body of knowledge. This schema resembles the one proposed by Paraschivoiu et al. [8] who presented a review of persuasive systems in vehicles based on the Persuasion Interface Design in the Automotive context. Their framework integrates intents (the goals), cues (the way to persuade), persuasive principles and design options (notification system and technology used) for automotive persuasion.

Table 1. Different approaches to persuading a driver in the field of mobility

Acronym	Description	Notification System	Designed to	Technology	Article Reference
PDP	Persuasive Design Principles	Theory	Influence human behaviour	General	[16]
HCI	Computer Human Interaction	Multimodal notification interface	Driving safe, comfortable and efficient	Embedded into the car	[28]
ADAS	Advanced Driver Assistance System	Multimodal notification interface	Safety and Efficiency Driving	Embedded into the car	[29]

ITS	Intelligent Transportation Systems	Road panel notifications	Improve drive safety	Road panels	[30]
MIS	Management Information System	Road panel notifications	Information (places, petrol stations,…)	Road panels	[31]
TAM	Technological Acceptance Model	Theory	Technology use acceptance	General	[32], [33]
TAM2	Technological Acceptance Model 2	Theory	Technology use acceptance	General	[34]
TAM3	Technological Acceptance Model 3	Theory	Technology use acceptance	General	[35]
TRA	Theory of Reasoned Action	Theory. TAM predecessor	Technology use acceptance	General	[36]
TRAM	Technological Readiness Acceptance Model	TAM evolution	Technology use acceptance	General	[37] [38]
DAS	Driver Artefact System	Based on OBD-II device	Real-time recommendations	OBD + APP	[39]

In Table 1, eleven types of technology elements that can influence on people and, more particularly, influence drivers were analysed. The application of the principles of persuasion (PDP) in drivers was examined. Furthermore, different systems and technologies related to interacting with drivers, inside and outside the car are addressed. In this context, Computer Human Interaction (HCI) as a multimodal notification interface designed to facilitate the driving [28] has been reviewed. The Advanced Driver Assistance Systems (ADAS) was also included because it is a technology system for safety notification interfaces in real time while driving [29]. In terms of filling the need of reviewing the road infrastructure notification panels, the Intelligent Transport Systems (ITS) were also analysed. This system corresponds to a set of road infrastructure solution that are designed to improve the safety and comfort of drivers and passengers [30]. The literature referring to demand/respond to incentives with the aim to achieve economic benefits was also included in the study of the existing research. In this field, the Management Information Systems (MIS) is the technology model analysed. This technology is oriented to cause changes in a driver's with respect to a usual pattern of consumption, in response to price signals or incentives on roads [31].

The acceptance of new technologies through TAM (Technological Acceptance Model) was also considered. TAM is a theory of information systems that models how users accept and use a technology [25, 27]. This model is based on the fact that it can be inferred through analysis if a society is more inclined to incorporate novelties or, on the contrary, is conservative. TAM is analysed, as well as its predecessor, namely Theory of Reasoned Action (TRA) [36]. Attempts have been made to develop several derivations of this model namely TAM 2 [34] ; TAM 3 [35], Technology Readiness and Acceptance Model (TRAM) [31, 32]. Bombillier Chaumont [40] describes the process of acceptance of technology as a trajectory that goes from the beginning of the design of a system until its implementation. From this notion, different authors [38, 39] identify two important stages: the preadoption stage, which corresponds to social acceptability and the subsequent stage, which corresponds to practical acceptance. Finally the acceptance associated to the use of evaluating an IT artefact in real-time has been analysing as well [39] has also been studied. Therefore, it tries to understand how an IT system can be integrated or not into the socio-domestic practice for drivers, which will could modify or transform the travel organization, car services or car maintenance [37].

At the bottom of the table, it has been included what it was called DAS (Driver Artefact System) which is the system analysed by this paper's authors. As has been explained in Section 2, DAS is a system that depending on the drivers' ontology and pattern analysis offers an ad-hoc solution in real-time through a technological artefact.

Up to now, in this review, it is observed that there are many technological elements that are designed to try to influence drivers' behaviour. Most of them were devised to make technology more accessible, more understandable, and even simpler to drivers. Some of them, in terms of mobility, try to help the driver to be more efficient and safer on the road. However, from the best of the author's knowledge, there is no existing research that employs ICT-based artefacts to help and influence drivers to save time and money in his/her car mobility activities in real-time. More in depth, no evidence has been found throughout the literature review about which kind of persuasion principles would apply better to each driver in different contexts.

4. Methodology / Procedure

This section explains the methodology framework as well as it fulfils the goals that were stated in the introduction section. The methodology approach consists of using the DAS artefact to collect real time data and to use such data to influence drivers towards saving money around car *ad hoc* needs (e.g., maintenance control, engine failures, enhance driving, etc.). As explained in previous sections, recall that DAS allows to know what is happening in the car and assists the driver to propose a maintenance/service solution if required. In order to evaluate driver's behaviour, the study of persuasive technologies is applied to understand which technological advantages can be used to motivate end-users. To such extend, a survey was created. Through this instrument, the respondents have to determine which of the persuasion principles presented were more relevant for them. Instead of asking users about the twenty-eight persuasive principles identified in the literature, only fifteen were included in this study. This decision was taken based on the reasoning of experts on persuasion and followed the same agreement-base rationale taken in a previous paper of the authors [5].

The survey was launched in an online format. The people who received and then answered the questionnaire were selected because they already had the DAS in their car. The access to those drivers has been possible thanks to an agreement with the company Grupo NEXT. The survey was sent to 1,500 drivers randomly in a blind selection process and after two weeks 308 responses were obtained. 301 of the responses were valid after a cleaning process and removing outliers. The data protection guidelines, the legal GDPR and anonymization policies were first agreed by participants before starting the questionnaire. It is important to emphasise that the authors of this paper did not have access neither to private information nor the identity of drivers. The respondents were informed about the purpose of the questionnaire and about its scientific use. Finally, users were informed that their participation was voluntary and some reminders were sent during the survey period to try to ensure an adequate participation rate.

In the survey, the end-users were asked to self-rate (from 1 to 7) strategies derived from the principles of persuasion that apply to this research. For each persuasion principle, a strategy was designed. See Table 2 where a mapping between the Persuasion Principles and the strategies of persuasion is outlined. The selection of the strategies on top of the fifteen persuasion principles was influenced by scholars' views in the field [9, 10, 38] and the authors' own criteria. As can be observed, purposely all the strategies are related to the use of the App of the DAS system.

Table 2. Mapping of persuasive principles & Strategies

Persuasion principle	Description	Strategy	Organize

P1. Principle of Tunnelling	It provides opportunities to persuade the user along the way. In our case, we use our IT artefact to persuade the end user to do things at every single opportunity.	The APP is available everywhere at anytime	S1
P2. Principle of Tailoring	The information provided by the IT artefact is more precise if it is bespoke to end-users. In our case, the communication with the end user will be optimized depending on the categorization.	The APP offers me "tailor-made" services	S2
P3. Principle of Personalization	The system is modified to meet the user's needs. A system that offers personalized content or services has a greater capability for persuasion. In our case, drivers will receive push notification messages (QR codes) through the IT artefact that can be presented on the suggested places (shops) to have rebates and discounts.	The APP can be customized by the user	S3
P4. Principle of Self-Monitoring	The goal is to allow people to monitor themselves in order to modify their behaviours, to achieve a predetermined objective or outcome. In our case, the drivers will receive full information of their savings through an App to check savings account.	The APP allows end users to monitor the behaviour and allows them to better reach the goals (control, savings, ...)	S4
P5. Principle of Simulation	Related with cause and effect. In our case, depending on the end user circumstances and ontology, opportunities will happen. The more information we have, the better opportunities we can suggest.	The more I use the APP, the more proposals I receive	S5
P6. Principle of Praise	Depending on the praise, DAS system can make users more open to persuasion	User receive praise through the APP	S6
P7. Principle of Rewards	The system could reward depending on the behaviour. Using our IT artefact, we suggest different reward systems focused on discounts and rebates.	The APP allows me to obtain savings	S7
P8. Principle of Reminders	The more you remind something to someone, the more the users will achieve their goals. To persuade the user along the way, we send some reminders to try to influence on the end user.	End user appreciate that the APP remind things that they can do or things that they can have	S8
P9. Principle of Suggestion	In an interactive computer product, it corresponds to its ability to suggest behaviour at an opportune moment. Application for a driver with real time solutions to car services with savings.	Proposals and suggestions come to me at the right time	S9
P10. Principle of Liking	Depending on the IT artefact visually attractive, we can be more persuasive. We are using digital marketing tools to persuade the end user.	The way in which the proposals come to me, it conditions my response	S10
P11. Principle of Expertise	A system that is viewed as incorporating some level of expertise will have more persuasive powerful. In our case we will use some Artificial Intelligence to describe the end	End user watch the APP as a sophisticated system	S11

	user ontology to try to be more precise in suggesting product and services.	and that encourages his/her to use it more	
P12. Principle of Authority	System should refer to end user with some level of authority. In our scenario we can suggest driving scores to try to influence on their driving risk.	The APP suggests me comments or actions that I take very seriously	S12
P13. Principle of Social Learning	The end user would be more motivated to perform our target behaviour if the system will provide info about others performing the behaviour. In our case, thanks to the gamification options, the end user will be compared over their peers in some mobility and driving aspects.	The APP allows me to compare myself with other users	S13
P14. Principle of Recognition	Offering private, public, individual or group recognition can increase the probability of targeting a behaviour. In our case, the targeting behaviour is a critical part of the IT artefact solution.	The APP shows me a recognition or scoring system	S14
P15. Principle of Kairos	The mobile systems of the future will be able to identify opportune moments and have more effective influences than they do today. The artefact will show to drivers; products and services, depending on the needs and circumstances at the right moment.	The APP helps me to identify opportunities and services at the right moment	S15

After testing the questionnaire with some pre-test participants, the authors decided that some of the strategies and principles could be grouped to facilitate the selection and, hence, ensure comprehensibility of the whole approach. Therefore, some principles and strategies were grouped together. Table 3 shows the strategies clustered into 7 "main strategies".

Table 3. Mapping of Persuasive Strategies to the Persuasion Principles

Strategy	**Definition**	**Persuasion Principle**	**Question**
S1	The APP is suitable for all times of the day	P1	1
S2, S3, S15	The APP offers me "tailor-made" services and can be customized by the user	P2, P3, P15	2
S4	The APP allows end users to monitor the behaviour and allows end users to better reach the goals (control, savings, ...)	P4	3
S5, S6, S7	The more I use the APP, the more proposals I receive where I like to receive praises for getting savings	P5, P6, P7	4
S8, S9	I appreciate that the APP reminds me things I can do or things that I have to do in real time	P8, P9	5
S10, S11, S12	The way in which the proposals, as a sophisticated system, come to me, it conditions my response	P10, P11, P12	6

S13, S14	The APP shows me a recognition and allows me to compare with other users	P13, P14	7

The aforementioned table explains the relationship between the questionnaire and the definitions/Persuasive Principles/questions. This means that question 1 refers to strategy 1 (S1), the question 2 refers to strategies S2, S3 & S15, question 3 refers to strategy S4, and so forth.

The questions used in the survey are included in the Table 4. Respondents were asked firstly for a prioritisation task in order to identify which of the strategies were most important to them and which were less relevant according to their criteria. Specifically, responders were asked to identify and rate the functionalities that the APP (part of the DAS system) offers with the aim of organizing them from the lowest to the highest relevance. The criteria was to give a score of "1" to the strategy that the user least identify with, or s/he liked the least. On the opposite, we asked to give a score of "7" to the strategy/functionality that one thinks that it can help her to use the app more and/or save more time and money. The objective was to not repeat any score in the 7 answers in a way the questions could be ranked. The questions were shuffled to avoid bias in the responses.

Table 4. Survey questions in the initial order

Nº	**Question**
1	The APP is suitable for all times of the day
2	The APP offers me "tailor-made" services and can be customized by the user
3	The APP allows end user to monitor the behaviour and that allows end user to better reach the goals
4	The more I use the APP, the more proposals I receive where I like to receive praises for getting savings
5	I appreciate that the APP reminds me things I can do or things that I have to do in real time
6	The way in which the proposals, as a sophisticated message system, come to me, conditions my response
7	The APP shows me a recognition and allows me to compare with other users

5. Results

To find a visual and simple way to interpret in a glimpse which strategies were the most interesting for the respondents, answers were weighted of each question. The weigh system was created following this scheme: if a respondent rated the first question with the highest rank such answer were multiplied by a factor of seven. If a respondent rated the second question with the second highest rank, that answer were multiplied by a factor of six and so on until reaching the last question that was multiplied by a factor of one, being this strategy the least interesting for the respondent. Same questions are always multiply by the same factors. With this weighting system, and after adding the ranking to each question from the 301 respondents, the results of the survey can be provided graphically.

As can be observed in Figure 5, answers 3, 2 and 5 are the ones that have obtained the best rankings. The strategy number 3 obtained the 17.69% of the answers, the number 2 the 17.47% and the number 5 the 15.39%. Those strategies (3, 2 and 5) refer analogously to: offering personalized services, allowing the car behaviour monitoring in order to reach the objective of saving money, and provide solutions and services in real time. In fact, the dominant strategies with higher rankings among respondents were those referring to personalise consumption control. The least important or lower ranked were those related with public recognition (question 7) and the way in which the answers arrive to the APP (question 6).

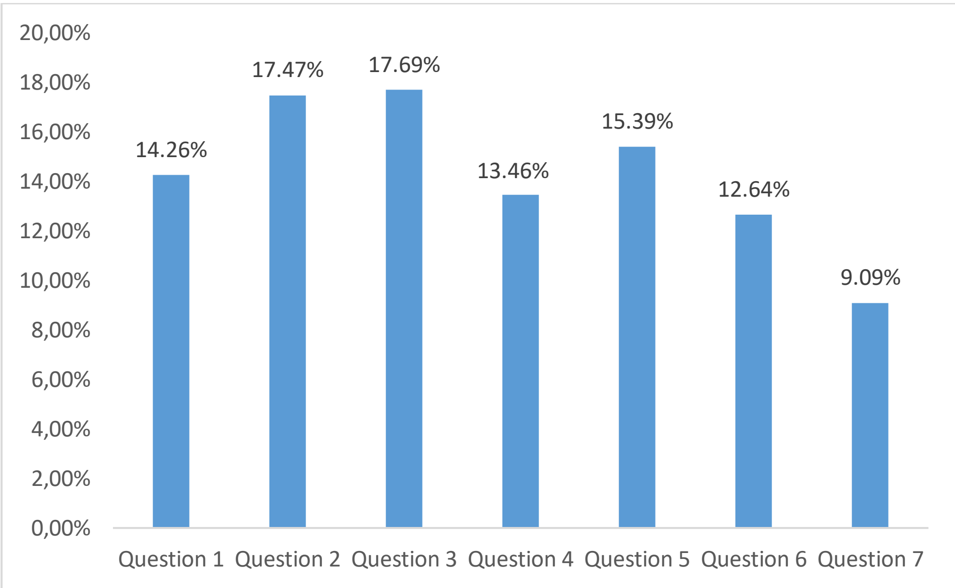


Figure 5 Weighted answers from the questionnaires.

To see if the results vary applying a different weighting factor to the rankings, Figure 6 is provided. It shows the results if only the best and worst ranking to different questions is taking into account. Thus, all other rankings are overlooked focusing only in the strategies the respondents prefer the most and the least. In this second approach, the strategies with the highest level of acceptance are number 3 and number 2 (personalized services and self-monitoring). Those with the lowest level of acceptance are number 7 and number 6. These last two answers are referred to: (i) if the end user is conditioned depending on the way in which she receives offers, and (ii) if the DAS shows to the driver a recognition system to allows his/her to compare with others.

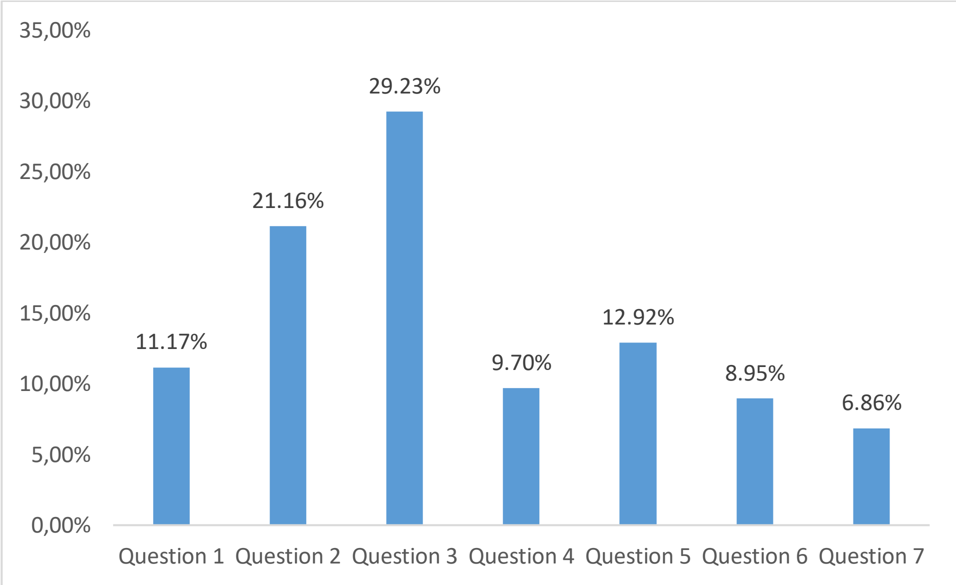


Figure 6. Best (7) and Worst (1) answers ranked for comparative purposes

In terms of Persuasion Principles, as can be observed in the Table 5, the top 6 principles that were highly rated are related with the Principle of Tailoring, the Principle of Personalization, the Principe of Kairos, the Principle of Self-Monitoring, the Principle of Reminders and the Principle of Suggestion. Overall, this analysis indicates that the most important value of the different Persuasion Principles are related to personalized recommendations to save time and money through the APP. Observing the impact of the technology in drivers it can be concluded that the Persuasion Principles are effective to engaging driver behaviours, mainly focused on preparing customized messages, on time, in form and with a large cause-effect relationship. It could also be argued that is important to know that people are ready to admit recommendations if those recommendations are useful to make life easier to drivers.

One of the objectives of this article was to discover which persuasion principles best apply to designing a better IT artefact. The aim of this better artefact is based on increasing the use with more and better real time solutions to finally save money around the car mobility expenses. The best evaluated strategies could be a guide where it can be pointed out to develop a better IT artefact.

Table 5. Best evaluated strategies

Ranking	Question	Strategy	Principle	Principle Description
1	Question 3	S4	4	Self-Monitoring
2	Question 2	S2, S3, S15	2, 3, 15	Tailoring, Personalization, Kairos
3	Question 5	S8, S9	8, 9	Reminders, Suggestion

The results in terms of the worst evaluated Principles of Persuasions can be observed in table 6. The worst ranked were the Principle of Social Learning, Principle of Recognition, Principle of Linking, Principle of Expertise, Principle of Authority, Principle of Simulation, Principle of Praise and finally, the Principle of Rewards. It is necessary to point out that this article has a limitation because respondents were asked to express his/her opinion over an already existing IT artefact. Such artefact does not still feature functionalities related to the capacity of provided rewards, recognition and/or liking. Therefore, the worst evaluated strategies seems to be those which are not yet available in the current version of DAS. This is a relevant comment since an otherwise designed IT artefact could alter the presented results.

Table 6. Worse evaluated strategies

Ranking	Question	Strategy	Principle	Principle Description
1	Question 7	S13, S14	13, 14	Social Learning, Recognition
2	Question 6	S10, S11, S12	10, 11, 12	Liking, Expertise, Authority
3	Question 4	S5, S6, S7	5, 6, 7	Simulation, Praise, Rewards

6. Conclusions, recommendations and future work

Considering the overall objective to be the persuasion and practice of dominant technologies, this paper has studied and analysed the implementation of persuasive design principles in a real manner. This work has assessed the impact that persuasive technologies may have on a user's behaviour. As a result, a selection of the best persuasion strategies to aid drivers has been performed. According to the definition of persuasive technology which considers any interactive computer system designed to change the attitude or behaviour of a person [16], the analysed DAS devices can be considered an element of persuasive technologies.

The work presents some of the main concepts and models in the persuasive technology framework. Firstly, focusing on the definition the persuasive technology that must be addressed intentionally and influence on a user's behaviour through the implementation of technological components. Secondly, the technological components used to influence user behaviour were analysed. This enabled to bring together the two concepts that are intended to influence behaviour through inherent motivations of individuals. Finally, a survey was presented to observe the responses of the participants to rank the strategies derived from the Persuasive Principles. In this context, a systematization of persuasive design principles was carried out.

The best strategies to design an IT artefact with Persuasion Principles embedded for drivers have been pointed out. Developing a driver's taxonomy can open a relevant work horizon since this research is a starting point towards more personalized technology elements based on AI that allows a higher level of personalization solutions. Better strategies could be translated in creating better IT artefacts to produce better results in terms of solutions to real needs with savings. The way to present those products or services is critical. Responders have helped to identify the right strategies to design a better DAS artefact. In that context, there is a line of research for future work to create better customized IT solutions based on those Persuasion Principles. The engaging mechanisms through the customization need to be considered as a real tool to develop an IT artefact, beyond the economic incentives. The recommendation for creating a new APP's will be oriented to augment the personalized messages to alert the driver, rather than adding new interfaces due that persuasive applications targeting attitude are almost entirely lacking. Tailoring, Personalization, Kairos, Self-Monitoring, Reminders and Suggestions are accordingly designed to promote behavioural change. In this context, this work has found how to better design an IT artefact for the car industry to impact in the end user and invite her to save money and time. It is also important to observe that the participants in the survey were people with a high confidence in technology because they are using it in a daily-based. Future steps will seek to understand the differences between people that currently are using technology in their cars in comparison with people that do not. Beyond this and as a result of this article, it will be considered to enrich the already existing artefact by implementing mechanisms to promote the most effective Persuasion Principles Strategies that have been identified in the questionnaire.

Our approach to select the best Persuasive Principles to create car IT artefacts for giving answer to real time needs can also be applied to other areas such home supplies (electricity, heating, water,…) and personal expenses (hotels restaurants, trips,…) to mention only two options. This article oriented to select the best persuasion strategies could be the basis for an effective way of reducing costs in different areas and this could be the starting point for these future studies.

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CAPITULO 4: El vehículo conectado como mediador del ahorro para conductores de turismos

4.1 Introducción al artículo científico y principales contribuciones

El presente capítulo aborda el papel que juega el IoT (Internet de las Cosas) en el mundo del motor. En este caso se analiza el papel que desempeña la tecnología en reducir los gastos corrientes alrededor del mantenimiento del automóvil. Cuando hablamos de gastos nos referimos a los gastos de la movilidad del vehículo, tales como el combustible, el seguro, el parking, los peajes, las averías y los mantenimientos.

El artículo pretende validar la hipótesis de que el coche conectado reduce los gastos respecto a un vehículo no conectado (SH3). Además, este artículo analiza brevemente la sub-hipótesis SH1.

Para ello se realizó un doble trabajo;

1) Por una parte, se reunió a un grupo de expertos que mediante el método Delphi determinaron las variables más relevantes que influyen en el gasto alrededor del vehículo

2) Posteriormente se analizó, a través de una encuesta entre conductores de vehículos conectados que se contrastó con la misma encuesta dirigida a vehículos no conectados. La idea no era otra que la de verificar que los determinantes o variables más relevantes que los expertos habían señalado contaban con un refrendo real del mercado.

En base a ello, se pudo concluir que los gastos de los conductores con automóviles con dispositivos de IoT, que convierten sus coches en coches conectados, son menores que los que tienen automóviles convencionales. El impacto del ahorro de los vehículos conectados es de 0,012€ por kilómetro frente a los vehículos no conectados. De media, por tanto, la diferencia es de 180€ anuales (tomando como base un kilometraje anual de 15.000 Km). A continuación se presenta el artículo donde la metodología y las conclusiones del mismo se pueden revisar en detalle.

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4.2 The Role of IoT Devices in Sustainable Car Expenses in the Context of the Intelligent Mobility: A Comparative Approach

Article

The Role of IoT Devices in Sustainable Car Expenses in the Context of the Intelligent Mobility: A Comparative Approach

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Abstract: Connected cars have often been defined as vehicles that can provide some services and information without human intervention. Several scholars have examined the factors that promote the purchase or adoption of such augmented vehicles. However, little emphasis has been placed on the determinants for reducing car expenditures when a driver owns a car with an Internet of Things (IoT) device or a smart assistant in the context of the smart mobility. Therefore, this article analyses whether emerging technology such as IoT plays a key factor for a driver on the expenses related to the car (e.g., insurance, maintenance, and repairs). To this extent, a methodology based on an exploratory (i) and confirmatory analysis (ii) was carried out. The authors initially conducted an exploratory phase by means of a Delphi method in which a group of vehicle experts (N=25) were recruited to give their opinion and reach an agreement defining the determinants that they believed affected vehicle expenditures the most. Secondly, and taking into consideration that the salient determinant from the Delphi method was the use of technology and the warnings and alerts it triggers, a questionnaire was delivered to 556 drivers to analyse the everyday spending on their cars. Specifically, the survey aimed to compare the responses of people who own connected cars or have any kind of IoT infrastructure built-in (N= 302) with people with non-connected cars (N= 254). The main conclusion obtained for this latter approach was that drivers with a connected car have remarkably lower car expenses than those driving a conventional car.

Keywords: connected car; IoT, determinants; Delphi method; survey; car expenditure.

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1. Introduction

Over the last few years, the automotive domain has been evolving rapidly. One of the different challenges vehicle manufacturers are tackling is the transformation of their innovation approach from offering efficient engines to increasable more software-driven machines. The beginning of a new revolution in the automotive industry has just started, where the concept of technology-connected cars will transform the vehicle completely [1]. The challenge does not lie any longer in waiting for manufacturers to develop new car models equipped with sufficient technology, but rather in embracing the opportunity to transform a conventional vehicle into a connected car through the installation of technological devices [2]. The increase in technological development and the globalization of markets, the creation of the concept of smart cities and the economies are significantly changing the environment in which companies operate. This changing landscape in companies is proof of the progressive adherence to Information Technologies (IT), telecom, and even robotics nowadays.

Internet of Things (IoT) devices embedded in vehicles can play a relevant role as they can help to transform our cities. Thus, smart mobility is one of the pillars for the design of the new smart cities. If vehicles become smarter through IoT devices embedded into them, it could be possible to link vehicles with infrastructure. This infrastructure could help us to create more sustainable cities savings cost and CO2 emissions for citizens and governments.

A connected car is defined by Coppola and Morisio [3] as "a vehicle capable of accessing the Internet, of communicating with smart devices as well as other cars and road infrastructures, and of collecting real-time data from multiple sources". The vehicle, therefore, ceases to be a system that only transports us and becomes a transport means that can help us satisfy our daily needs. A vehicle may cover our needs in real time by providing the most accurate products and services available at that time. This technology must be able to control some parameters of the car and interact with the vehicle and its driver. This underlying technology is recognized as IoT.

As an additional description and according to Swan [4], "the connected car means a continuously Internet-connected car, generating and transmitting data". These data can prevent fatigue, provide real-time assistance for accidents, and assist cars in performing remote diagnostics.

According to a study by PriceWaterhouseCoopers [5], 40% of the mileage will be made by autonomous vehicles in the European Union (EU) by 2030. In that same year, the pool of vehicles is also expected to fall from 280 million to 200 million. This represents a 28.5% reduction in the passenger car pool. Thus, we are witnessing a change of paradigm because there will be less demand for vehicles, but they will have to last longer, so the maintenance of the vehicle becomes paramount. This trend is also confirmed by the maintenance cost of electric vehicles, which is much cheaper than that of petrol cars. An opportunity is, therefore, arising for the aftermarket car industry (car maintenance, repairs, etc.) as vehicles will have more activity transforming the structure of our cities as well. Furthermore, according to the same report, vehicle manufacturers are gradually becoming software development companies to ensure that the needs of the autonomous car are met. In addition to this, the world of the connected car is carving a niche in the evolution of a more technology-based society in terms of mobility and smart cities. In essence, this change of paradigm toward longer lasting cars will have an impact on the way people maintain their cars. In economic terms, as an average, and following the internal figures of Grupo Next Mobility Company[2], it is estimated that in the EU, a passenger car costs around EUR2,000 per annum. Any variation below this would suggest significant savings for the drivers and for the environment, since better or reduced driving behaviour leads to reduced pollution. Indeed, the revision of some basic elements of the vehicle (oil, filters, tires, etc.) helps to reduce the amount of consumption of the car itself, and, therefore, a well-maintained vehicle helps to reduce CO_2 emissions [6].

In conclusion, embedding technology in the vehicle should be the catalyst for developing on-demand service models. By equipping cars with connected car technology, it is becoming easier today to control and determine how much a vehicle drives, how it is driven, what inspections it needs, or how much it spends on petrol when detecting the vehicle being parked next to the gas station pump hose. This is a reality and not only what is going to happen in the future. The emergence of the connected car, therefore, will help to increase the safety of the car and its occupants and will provide more efficient (in terms of cost and pollution generation)

[2] www.gruponext.es

driving, being the prelude to future autonomous driving [7] and the transformation from the "old mobility" to the "new mobility". In terms of giving some context to the reader, the difference between connected car and autonomous car is that the first one reads the internal sensor and has connection with the infrastructure and the second drives automatically by sensing the surrounding environment and taking driving decisions.

As technology (car instrumentation) can play an important role for drivers, this article examines the role of introducing this technology around car expense management. For this objective, a participatory survey was sent to a group of experts (N = 25 at the beginning, but only 22 remained after the full study. Thus, three people left the study or did not completed it in total) and followed up with a Delphi method [8] [9]:

1) The objective of the Delphi method was to identify which determinants they believed had the highest impact on the money that drivers spent on their cars. Once these determinants were ranked by all the expert participants and an agreement reached following various rounds of the Delphi method, it was determined that technology has a salient role in forecasting drivers' expenditure on their cars, outperforming other determinants such as marketing campaigns or previous knowledge of the driver.
2) To confirm the outcomes from the exploratory analysis, a questionnaire was created to obtain evidence from everyday drivers. The survey was conducted to evaluate and compare the spending level of drivers who own a connected car with regards to those that have non-connected conventional cars.

A sample of 556 drivers was gathered, where the drivers were divided into two groups: people with assistive technology (connected cars) in their cars and drivers of conventional cars without technology equipment incorporated.

After the comparison of the responses of the two sample groups, it was possible to answer the main research question of this article: "Does technology play a key role when it comes to reducing the everyday expenses around the car?". To be more precise and for the sake of avoiding misunderstandings; when the authors refer to car expenses, they are talking about the following costs: petrol, insurance, maintenance, car service, garage, tolls, penalties, taxes and repair costs. Hence, this paper aims to validate the following associated hypothesis: "connected cars through emerging technology reduces car expenditures in comparison with non-connected cars".

The article is organized as follows: First, we review the relevant literature in three different categories related to the domain of this paper: (i) connected car services, (ii) variables affecting car usage, and (iii) the role of technology in reducing costs. Secondly, the Delphi method and an in-depth follow-up survey used to conduct an exhaustive study on driver's behaviour regarding car expenditure are described. Thirdly, the paper includes the results of both studies and gains insights from their analysis. Finally, the paper draws some conclusions and suggests further areas for study.

2. Literature Review

This section reviews the variables that could affect car consumption and the technologies that could play an active role in reducing expenses around the car. Figure 1 depicts schematically how the literature review process was carried out. As can be observed, three categories of analyses have been performed:

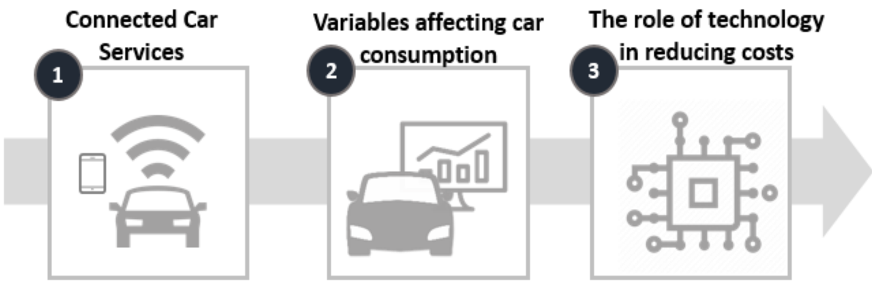

Figure 1. Literature review framework.

2.1. Connected car services

The field of the connected car is part of the world's evolution. In this sense, the introduction of the Personal Computer (PC) in the field of domestic use could be considered the first step and, subsequently, the Internet revolution was the second. Today's world is hyper-connected, and the car is no exception [4]. As Swan [4] also indicates, the greatest limitation of a connected car is data privacy management. In the same context, all of those humongous amounts of data could be used to generate different business models [10].

Data are fundamental to value creation and present a competitive advantage in the smart domain [11] [12]. All data collected and processed from the car can be very valuable if they are shared properly [13]. Thanks to data a lot of services could be generated around the car [14].

There is another important implication of connected cars in the management of the city. It could be seen as a system that can be shared with the local authorities in order to send alerts in certain scenarios such as possible crashes or significant car failures [15]. Datta et al. [15] indicate that the connected car system can be used to develop a V2X (Vehicle-to-Everything) connection, to monitor car mobility and environmental conditions and deploy different services around the mobility ecosystem.

On average, 20% of new car buyers state that they would be willing to switch to a different car brand for better connected car services [16]. Mikusz and Herter [16] define car services as services based on the intelligent connection of the vehicle with its environment such as transportation infrastructure, other vehicles, and drivers. However, we should not forget that all of these services need to be relevant to the end user. Hebeler and Hofmann [17] argue that many connected car services are put in place without monetary value for the customers.

"Connected car" is a terminology often associated with applications to better manage the car maintenance and services such as tires changes and car maintenance. [15]. The evolution of the connected car, taking into account technology maturity levels, driving factors, and business models of connected cars has been deeply studied by Möller and Has [18].

2.2. Variables affecting cars' expenses

Few earlier scholars' works have been interested in exploring this domain. There are many variables that can play a significant role affecting cars' expenses [19]. Fuel consumption is one of the most relevant costs in car use. Parry [20] indicates that a 9.1% reduction in fuel consumption can be achieved owing to embedded technology in the vehicle. Thus, information & communication technology (ICT) may work as an element of persuasion, transforming drivers into more informed people who are therefore sensitive to spending more wisely.

Regarding what can be considered car expenses and how they vary, Kim, Hwangbo, and Kim [21] indicated that expenditures may vary depending on the type of driving, the driving circumstances, the type of car, the speed with which it is driven, and other factors related to the car use. There are other studies [22] that show that 44.33% of buyers of electric or hybrid vehicles are also buyers of home solar panels. A total of 12.67% indicate that they have not yet bought solar panels, but they are planning to buy them soon. If both percentages are aggregated, it can be deduced that 57% of the people who drive a sustainable vehicle (in environmental terms) are also eco-driven in other activities of their ordinary life. This is a relevant factor since technology can help to condition the attitude of people, and people who adopt an attitude as a pattern of behaviour evolve according to that pattern [23].

2.3. The role of technology in reducing price and environmental costs

The existing literature has focused mainly on measuring some car parameters for the purpose of car activity control [24]. Some authors have focused on car maintenance control through radio frequency systems installed on roads. The ability to check a car remotely through technology (e.g., change of oil, change of tyres or change of brake pads) is part of what is sought in this literature review. According to car manufacturers, managing a vehicle on time always has an impact on direct and indirect cost reduction since a possible deterioration is expected if the vehicle does not attend to the necessary maintenance tasks on time. In this way, Lin et al. [25] mentioned in their research that with the introduction of remote on-line diagnostic systems connected into a car, the time of fleet management and repairs can decrease significantly.

There is a current trend that is looking at the impact of selling mobility instead of cars. According to an empirical analysis from Firnkorn and Müller [26], private vehicles were reduced as a result of a consumer reaction. This theory confirms that a vehicle is observed as an expense generator and there are, according to the same study, some users who want to pay only for their mobility service. Other studies have reflected on the link between the use of technology and energy [27] and between the management of energy efficiency using technology and gamification [28]. Until now, no written evidence has been found in the scope of car use and savings management.

Apart from this, different authors point out that it is necessary to further the analysis of the type of maintenance service that can be offered to a driver in real time owing to the adoption of new technologies (e.g., [29]). This call for research is focused on the management of automatic calls for car maintenance and repairs [25], the collection of vehicle data for new services [30], and new business models for the automotive world [31]. In summary, having reviewed the state of the art in this field, this paper aims to fill a gap in existing mobility literature regarding the identification of what variables are most important concerning car expenditures, and the paper shares the results in an empirical analysis of the variables.

3. Methodology

Two different, yet interwoven, methodologies were applied to help answer the research question of this article. (i) On one hand, a Delphi method was used to identify which determinants a group of experts believe had the most impact on the money car drivers spend on their cars; and (ii) on the other hand, a survey was conducted to analyse whether two population samples, one with connected cars and another without any technology installed in their car, develop different conducts in terms of how much money they spend on their cars or not and the confidence they have on the answers given. In essence, the results of the exploratory Delphi methodology provide information on experts' opinions and trends in car expenditure [32]; the results of the survey with everyday drivers provide confirmatory information about what is happening in a real scenario and validate the findings provided by the experts. Next, the two approaches to identify determinants and then confirm the validity of the most important one are explained.

3.1. First phase: Delphi method adapted within a COVID-19 context

The study was structured into six phases as can be seen in Figure 2. This methodology was planned and implemented during the COVID-19 pandemic period where face-to-face individual or group interviews were not able to be carried out. Hence, a decision was made to adapt this methodology to the new reality at the time of study. Therefore, we got inspired by Sawhney et al. [33] who already used an adaptation of the Delphi method due to the COVID-19 pandemic in their research to conduct our research method.

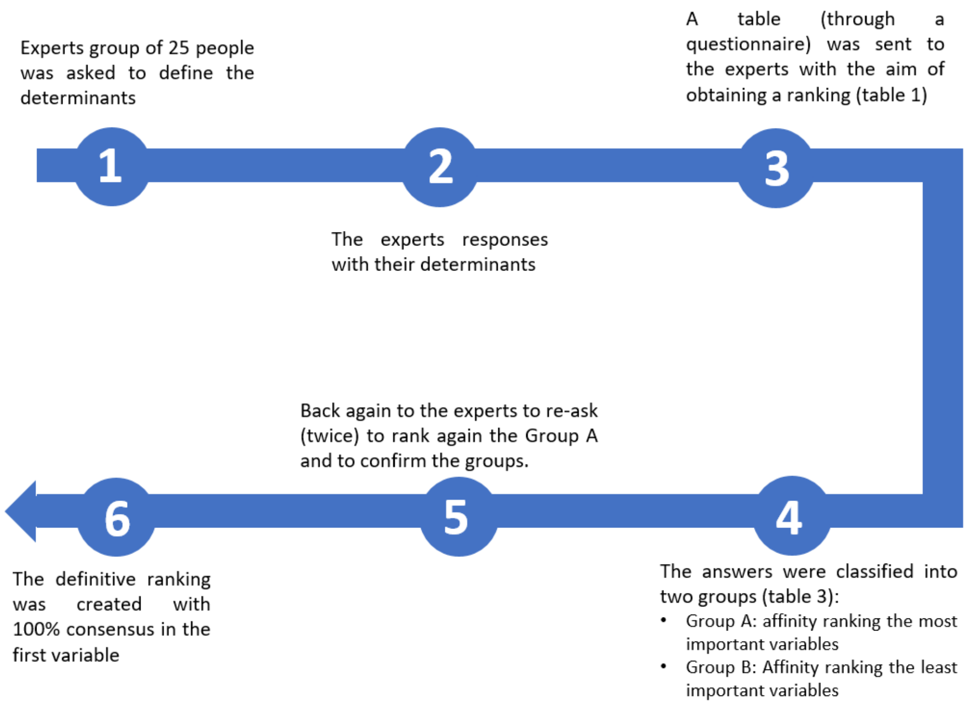

Figure 2. Delphi method description along with its six phases.

The following six phases of Figure 2, explained below, were pursued:

A group of 25 experts, in different fields, were selected to explore what determinants would have the greatest effects on their car expenditure from different perspectives (e.g., engineers, behavioural scientists, market analysers, etc.). The experts were selected from different fields of the automobile world, digital transformation, insurance, garages, and digital marketing. The criteria for selecting the experts considered the idea of covering as wide a range of knowledge as possible. This was possible due to collaboration with Grupo Next, a mobility company. Its CEO and co-author of this paper assisted in the selection of the experts based on his long experience in the mobility industry (more than 25 years). Thus, of the 25 experts, 4 are experts in digital marketing, 3 in the insurance industry, 3 in the world of connected mobility, 2 in customer services, 3 university members who are experts in digital transformation, 3 experts in data processing, 2 experts from the OEM aftermarket world, 3 experts from the automotive industry and 2 experts from the financial world and digital payment services. All of them are high ranking executives, i.e., high ranking executives in their organizations. A determinant, in the context of this research, is defined as a factor or construct with a set of characteristics that defines the spending behaviour of a driver around the car. In this sense, a personalised e-mail was sent to each expert. Each expert was asked to indicate the determinants that they believe are the most relevant in terms of influencing driver's behaviour reactions in car expenses. They were asked to give a minimum of five determinants. The format of providing the information was open and unstructured. Thus, they were asked to reply to the email only listing their top selection of determinants associated with a description of them.

Through an on-line Google Form, experts were provided with Table 1 (see the results section) and asked to rank the list of determinants according to their criteria. To avoid any bias in the responses, the determinants were presented in a random order to each expert. It was explained that the higher a determinant was placed in the list, the more relevant that determinant was for the expert in terms of implying the highest impact on drivers' expenses, according to the expert's opinion. On the other hand, assigning a ranking of 10 meant that such a determinant had the lowest impact on car expenses.

Once they completed this initial ranking, another set of instructions was sent to the experts to find a consensus on the most influential determinants. The idea was that they should reflect on the presented averaged rankings based on multidisciplinary knowledge from the all experts responses. Therefore:

1) They had to first answer whether they agreed or not with the variables included in Group A (top-5 averaged determinants averaging the responses from the first phase). We also presented to them a Group B of the least voted determinants.
2) If they answered positively, they had to rank their personal Group A determinants according to their expert criteria where a determinant placed in the first position meant the best ranking for them and the one in the fifth position was considered the least important.
3) If they had answered negatively to the previous question, then, they had to suggest a new ranking, with the possibility of combining or changing a variable from one group to another (Groups A and B, see Table 3).

The information gathered from the experts helped the authors to gain insights regarding which determinant was the most important for experts (ranked in the first position) and which was the least important for most of them; a summary table was created to this extent (see Table 4 in the results section).

3.2. Second phase: Comparative survey method

After using the Delphi methodology, and to complement it, a survey was launched to compare the savings of drivers with connected vehicles with those of non-connected vehicles regarding car mobility scenarios (i.e., the vehicle is in a certain area at a certain time, so it is advisable to suggest a certain action to the driver) and the vehicle itself (e.g., it needs fuel, a service, or an oil change). This method was used to confirm the findings of the experts in the exploratory phase.

The idea of the survey was to confirm if the determinants driven by the experts are indeed those with highest impact on real scenario or not. This survey was part of a global data collection process performed within this research. The whole questionnaire can be consulted in the following link (in the author's mother language[3]) or in the Appendix I.

Hence, a survey was launched in an online format, again using Google forms, in order to evaluate and compare the spending of drivers of connected and non-connected vehicles. In both cases, the link to the online form was sent by email. Such survey was sent out to 1,500 drivers with connected vehicles, and a snowball sampling technique [34] [35] was used to send the same survey to drivers of non-connected vehicles. As will be shown later, 302 valid responses from users with a connected car and 254 responses from drivers without connected cars were collected. Both sample datasets (for connected and non-connected vehicles) have the same country and the same geographical area, there was no electric vehicle in the sample. This sample is significant since it represents the average age of cars in Spain and includes people with very similar social-demographic profile in order to avoid any kind of statistical bias. This made it possible to compare the groups and determine the impact of the stimuli received by drivers of connected cars on their expenditure and savings. The authors of this text reached an agreement with the company "*Grupo Next*[4]" to provide them with a sample of 1,500 drivers of connected vehicles. This company is one of the European actors of connected cars and offers users different services to make car-related activities easier to manage and cheaper. The completely anonymised sample of drivers making journeys in Spain was extracted from the company's database. In the case of the non-connected cars' drivers, through a snowball technique, we sent emails to different groups of collaborators who further sent the email to others, and these then sent it too many others until the number of drivers was like the one corresponding to the

[3] https://drive.google.com/file/d/13EIiXGI8Z6F-xexgUc1irUOxOr-9iMZB/view

[4] www.gruponext.es and www.nextsmartcar.es

connected cars sample. As earlier mentioned, all the vehicles in both samples represent the average car age in Spain (12.7 years average)[5].

The survey questions were validated through a group of experts before launching the form. The data protection guidelines, the legal General Data Protection Regulation (GDPR), and anonymization policies were first agreed by participants before starting the questionnaire. It is important to emphasise that the authors of this paper did not have access neither to private information nor the identity of drivers. The respondents were informed about the purpose of the questionnaire and about its scientific use. Finally, users were informed that their participation was voluntary, and some reminders were sent during the survey period to try to ensure an adequate participation rate. Additionally, it should be mentioned that the data were captured and analysed with the ethical validation of the process defined from the Research Ethics Committee of the University of Deusto[6].

All the drivers in the connected-vehicle sample had at least 6 months of experience with the ICT-based system and, thus, had experience with a device installed in their vehicle that could keep track of their mobility. This point was very important as the purpose of the study was to measure the impact of the technology on the expenditure and savings of both sets of drivers and their behaviour regarding car maintenance and expenses management. Two reminders were sent to those in the selected sample until the collection was considered final.

The survey questions can be consulted after translation in Appendix I. These were prepared based on 3 criteria: (i) identify the car and its uses; (ii) the expenses around the car and the vehicle mobility; and (iii) the driver perception of vehicle expenses. The rest of the survey questions could be consulted in the link aforementioned.

The first survey section contained 4 questions to identify the car and its use. The second section contained 6 questions to understand the expenses around the car and mobility patters in a year basis. All of them had 5 response options (a scale of expense ranking and DN/DA "don't know, don't answer". The last section (section 3) contained 2 questions related to driver perception of vehicle expenses and had 6 multiple choice response options based in a Likert scale: very low, low, regular, high, very high, and DN/DA. The same questionnaire was sent to both samples to avoid any bias. Finally, it is worth mentioning that most of the questions were followed by a confidence criterion. Thus, when we asked to drivers about the expenses they do in their car in a yearly basis, we then asked them to provide the confidence rate from 1 to 10 for such response where 1 was a poor confidence in their response and 10 a complete confidence on what they responded. We used this confidence criteria to weigh the responses given by drivers when we computed the average expenses by year. Furthermore, it helped us to compare if the drivers with connected cars are more confidence on their responses that those without connected cars. That is, if the technology also plays a role in the acquaintance people have over their driver expenses.

4. Results

4.1. Delphi Results

Following the description and definition of the Delphi method explained in the section 3, in what follows the results are presented.

1) 24 experts (one of them did not respond at this stage, so we decided to continue with 24 experts instead of 25 in order to not stop the process) responded with their determinants

[5] https://www.lavanguardia.com/motor/actualidad/20210125/6197134/espana-parque-automovilistico-edad-media-coches-viejos-paises-europa.html

[6] https://www.deusto.es/cs/Satellite/deustoresearch/en/home/research-with-us/research-ethics-comittee/composition

and these were examined, curated, grouped, adjusted, and finally formatted in a table (see Table 1)

Table 1. Experts' responses grouped together by the ten most prominent determinants.

Determinant No.	Determinant description
Determinant 1	On-board technology with warning messages generated by the system could influence car expenses' decision making (showing potential failures and maintenance reminders).
Determinant 2	Promotions launched by Original Equipment Manufacturers (OEM's) and automotive industry could influence decision making for vehicle maintenance and expenditure.
Determinant 3	Marketing, communication, and promotions are elements that could actively influence driver's maintenance expenditure decision making.
Determinant 4	Marketing campaigns generated by automotive brands and dealerships could influence maintenance expenditure decision making.
Determinant 5	Point of sale distance could actively influence drivers' maintenance expenditure decision making.
Determinant 6	The vehicle's type of use (professional or personal, weekday or weekend) could actively influence drivers' maintenance expenditure decision making.
Determinant 7	Apps and websites in the field of cars could actively influence drivers' maintenance expenditure decision making.
Determinant 8	Recommendations from family or close friends could actively influence drivers' maintenance expenditure decision making.
Determinant 9	Comments and recommendations from friends in the automotive field could actively influence drivers' maintenance expenditure decision making.
Determinant 10	New transport policies (e.g., 30 km/h zones) and their impact on the environment could actively influence on drivers' maintenance expenditure decision making.

2) A total of 22 experts, out of the remaining 24, responded to the questionnaire to reach an initial agreement when it comes to prioritize which determinants were more or less important. We, therefore, had an attrition rate of three people who did not respond to the questionnaire after several gentle reminders. The results of the first averaged ranking among the 22 experts can be observed in Table 2. Again, the information was input into a personal database of the research team for further analysis.

Table 2. Experts' determinant ranking.

Averaged order	Determinant No.
1	Determinant 4
2	Determinant 5

3	Determinant 2
4	Determinant 3
5	Determinant 1
6	Determinant 6
7	Determinant 7
8	Determinant 8
9	Determinant 9
10	Determinant 10

The determinants from the first consensus round were then clustered into two groups: Group A and Group B. Group A included the five factors that reached more consensus in terms of being the most relevant determinants for car expenditure according to experts' criteria (i.e., Determinant 4, 5, 2, 3 and 1); Group B included the other five determinants which received fewer votes out of the total 10 determinants (i.e., Determinant 6, 7, 8, 9, 10). They were presented according to the aforementioned criteria (see Table 3) and presented again to experts for the second consensus stage according to the Delphi method.

All data analysis was conducted in an MS-Excel spreadsheet.

Table 3. Group A and B creation and associated ranking from the first round of Delphi method.

Group A		
Averaged order	A	Description
1	A1	Marketing campaigns generated by automotive brands and dealerships could influence maintenance expenditure decision making.
2	A2	Point of sale distance could actively influence drivers' maintenance expenditure decision making.
3	A2	Promotions launched by OEMs and automotive industry could influence decision making of vehicle maintenance and expenditure.
4	A4	Marketing, communication, and promotions are elements that could actively influence drivers' maintenance expenditure decision making.
5	A5	Onboard technology with warning messages generated by the system could influence car expense-related decision making (showing potential failures and maintenance reminders).

Group B

Averaged order	B	Description
6	B1	The vehicle's type of use (professional or personal, weekday or weekend) could actively influence drivers' maintenance expenditure decision making.
7	B2	Apps and websites in the field of cars could actively influence drivers' maintenance expenditure decision making.
8	B3	Recommendations from family or close friends could actively influence drivers' maintenance expenditure decision making.
9	B4	Comments and recommendations from friends in the automotive field could actively influence drivers' maintenance expenditure decision making.
10	B5	New transport policies (e.g., 30 km/h zones) and their impact on the environment could actively influence drivers' maintenance expenditure decision making.

After having presented the list of the determinants grouped in two categories, the group of experts was requested to rank the table again. This process was launched twice to re-confirm the answers (in two different days). Firstly, the group of experts concluded that the five determinants were indeed the most relevant in terms of drivers' level of spending around their car mobility. Secondly, they ranked those determinants as reflected by table 4. Thus, table 4 is the result of ranking table 3 according to the experts considerations. As shown, the highest ranked (top 1) determinant was " on-board technology offering warning messages generated by the car (IoT device)" regarding driver's expenses according to all experts opinion, followed by proximity and marketing campaigns.

Table 4. Final Delphi method ranking with the most popular determinants.

Ranking	Short Description	Determinant	Determinant Full Description
1	Driver Artefact System (DAS)	A5	On-board technology with warning messages generated by the system could influence car expenses decision making (showing potential failures and maintenance reminders).
2	Proximity	A2	Point of sale distance that could actively influence drivers' maintenance expenditure decision making.
3	General Marketing	A4	Marketing, communication, and promotions are elements that could actively influence drivers' maintenance expenditure decision making.
4	OEM Marketing	A1	Marketing campaigns generated by automotive brands and dealerships could influence maintenance expenditure decision making.
5	Promotions	A3	Promotions launched by OEMs and the automotive industry could influence decision making of vehicle maintenance and expenditure.

4.2. Survey Results

As explained above, the survey was launched and structured into three sections (See Appendix A): (i) the first section focused on general vehicle information; (ii) the second section focused on consumption and expenses information; and (iii) the third section referred to the perception of drivers regarding vehicle costs.

The purpose of the first section was to check whether there were any biases, patterns, or data that might suggest that the sample was not of an adequate size or could contain alterations disrupting the data collection process (e.g., one sample contained vehicles which were much more modern, differences in car age, etc.). As can be seen in Table 5, both samples were similar in terms of type of cars, year of car production, years of car position, and number of kilometres per year.

Table 5 Comparison of data of connected and non-connected cars (section 1).

Question	Connected Car	Non-Connected Car
Q1-Vehicle Brand	20 most popular brands in	20 most popular brands in
Q2-Vehicle year (Median)	2014	2013
Q3- How long have you had the vehicle?	5,82	5,58
Q4-No. of Km / year (Mean)	13,103.82	12,786.5

The initial step regarding the results of section 2 was to normalise the data of each sample (connected and non-connected cars) for each question (total of six). To do this, all the values were first translated into an expenditure index. For instance, if we asked about the Km per year and the response in the form was "between 10.001Km and 15.000Km" we translated that value to an average scalar (i.e., 12.500Km). These normalisations helped us to calculate average costs per year or the average cost per Km. Subsequently, we calculated the descriptive statistics for each of the users' data (Table 6 and Table 7). The data show a tri-normal distribution with a 99% confidence level. Therefore, it has been decided to use inferential statistical tests [36] for normal distributions to check if the values from the two populations were significantly different or not.

Table 6: Connected car statistical data (section 2 of the questionnaire).

	Q1 (Petrol)	*Q2 (Insurance)*	*Q3 (Maintenance)*	*Q4 (Car Expenditures)*	*Q5 (Recommendations)*	*Q6 (Savings)*	∑ *Q*
Mean	43,55	398,59	291,41	1516,61	32,97	55,43	1,18
Standard Error	0,66	8,91	7,96	33,09	2,26	3,14	0,00

Median	50,00	300,00	300,00	1750,00	18,00	45,00	1,17
Mode	50,00	300,00	300,00	1250,00	0,00	0,00	1,17
Standard Deviation	11,69	157,71	140,78	585,50	39,82	55,64	0,07
Sample Variance	136,55	24872,38	19817,89	342816,06	1585,62	3095,41	0,00
Kurtosis	5,28	-0,28	0,32	-0,09	0,16	-0,91	1,29
Skewness	-2,29	-0,08	0,53	-0,62	1,18	0,60	1,00
Range	50,00	650,00	650,00	2200,00	120,00	160,00	0,39
Minimum	0,00	0,00	0,00	0,00	0,00	0,00	1,03
Maximum	50,00	650,00	650,00	2200,00	120,00	160,00	1,43
Sum	13630,00	124760,00	91210,00	474700,00	10221,00	17350,00	358,22
Confidence Level(99,0%)	1,71	23,10	20,62	85,77	5,86	8,15	0,01

Table 7. Non-connected car statistical data (section 2 of the questionnaire).

	Q1 (Petrol)	*Q2 (Insurance)*	*Q3 (Maintenance)*	*Q4 (Car Expenditures)*	*Q5 (Recommendations)*	*Q6 (Savings)*	∑ *Q*
Mean	40,18	396,63	306,06	1508,33	21,72	60,67	2,39
Standard Error	0,97	12,85	11,56	42,96	2,32	3,83	1,19
Median	50,00	500,00	300,00	1750,00	0,00	45,00	1,18
Mode	50,00	300,00	300,00	2200,00	0,00	0,00	1,16
Standard Deviation	16,31	215,86	194,15	721,49	38,98	64,28	18,93
Sample Variance	266,09	46595,37	37693,70	520544,19	1519,82	4132,46	358,46
Kurtosis	1,15	-0,82	-0,69	-0,27	1,64	-1,45	251,99
Skewness	-1,59	-0,46	0,25	-0,89	1,76	0,43	15,87
Range	50,00	650,00	650,00	2200,00	120,00	160,00	300,74
Minimum	0,00	0,00	0,00	0,00	0,00	0,00	1,01
Maximum	50,00	650,00	650,00	2200,00	120,00	160,00	301,75
Sum	11330,00	111850,00	86310,00	425350,00	6126,00	17110,00	602,34
Confidence Level(99,0%)	2,52	33,34	29,98	111,42	6,02	9,93	3,10

Additionally, the total expenditure level of each of the respondents in each of the samples was compared in a yearly basis. Furthermore, these were calculated according to the kilometres travelled by each user per year. Finally, we averaged the total cost per year with the confidence level they gave to their responses (as can be observed in the questionnaire and at is has been explained above, after each question related to the estimated costs per year, we asked to rank from 1 to 10 the level of confidence of the answer they provided). The result of the level of expenses is as follows (see Table 8). As can be seen, the number of respondents is smaller than the numbers presented in the introduction. This is because we removed outliers and uncompleted responses in the questionnaire.

Table 8. Total Expenses and Average Expenditure in a year basis presented first without taking into account the confidence level and then weighting the data according to it.

	Connected Cars per year (N=302)	**Non-Connected cars per year (N=252)**
Total Expenses	EUR 2.758,0 €	EUR 2.979,8 €
Average expenditure per km travelled	EUR 0,210209 €	EUR 0,22752 €
Average expenditure per km travelled weighted to the confidence level of the given responses	EUR 0,183214 €	EUR 0,19555 €

To validate that the results from Table 8 are significant from a statistical point of view, we used the t-test with the following results. There was a significant increase in the overall cost per year and per Km in the people with non-connected cars ($M = 0{,}19555$, $SD = 0{,}0746$) compared to the respondents with an IoT device installed in their cars ($M = 0{,}183214$, $SD = 0{,}0676$), $t(552) = 1{,}9642$, $p < .05$. Please note that this parametric test was applied in the responses weighted to the confidence level.

The results of section 3 were averaged and mapped according to response levels on a Likert scale from 0 to 6, where 1 corresponded to "very low" and 6 to “very high” (0 for “DN/NA”). The results are as shown in Table 9. As a result, people with connected cars seem to have a lower perception of car mobility expenses than those with non-connected cars, whereas this latter result did not offer significant results from a statistical point of view.

Table 9. Perception of vehicle expenses (section 3).

Perception of Vehicle expenses	**Connected Cars**	**Non-Connected cars**
Q1 (% of expenses)	2,12	2,43
Q2 (Promotions)	2,81	2,57

5. Discussion

The experts selected for participation in the Delphi method pointed out in their conclusions that the technology embedded in the vehicle and the warning and messages it generates for the driver plays a decisive role in determining the expenses of the drivers of a vehicle compared to other well-known determinants such as proximity to the place where the car was bought or marketing campaigns. Based on this conclusion, the survey comparison conducted was suitable to explore and verify with real-life testing whether on-board technology could condition the maintenance expenditures around cars or not, and, thus, to determine whether there is positive spill over effects of having an on-board ICT-based device in the car or not.

It is interesting to note that the experts were not wrong since this paper empirically demonstrates that introducing technology in the vehicle reduces the car-related spending. The hypothesis stated at the beginning of the study was therefore confirmed. Drivers who install technology in their vehicles save more (spend less) than those without connected technology in their cars and are more aware about their car expenditures. As a result, it can be concluded that technology plays a key role in saving money and time related to car expenses.

The survey presented and the data gathered showed that drivers of connected cars have a clear tendency to track savings. Users with connected cars either save more or are more aware of savings thanks to the technology embedded in the car.

Expenditure on the car is important for people who drive a connected car but is not so much for people who drive a vehicle without built-in communication technology (because they are simply not aware of what technology can do for them). This leads one to think that the mere fact of having the technology and information makes people with connected vehicles more aware of the vehicle's annual cost. A major future lever for cars and its associated mobility services will be the adoption of 5G, enabling new services for the car, thereby making mobility related activities more comfortable and satisfying.

While car mobility has brought enormous value to society over the past 100 years, there is still room to advance, particularly regarding efficiency, mobility cost, and car usage. There is great unexplored potential to study the impact of introducing technology to reduce expenses around cars, such as road infrastructure (free highways or highways), driving route information (more or fewer kms), and repair shops (with auction reverse). In this sense, technology should be viewed as an essential part of the car, and this technology should be connected to the different product and service providers to matchmake the drivers' real-time needs with the best possible solutions in each case. In addition, connected car technology can play a very important role in reducing CO2 emissions due to smart recommendations that help optimising car usage (e.g., predictive and smart recommendations on parking can reduce around 10% of CO2 emissions by removing ineffective time spent by drivers on searching for parking spaces [37], which is 20 minutes, and the traffic generated from it).

It is worth pointing out that connected cars not only help changing the user's behaviour but also have further advantages since this type of technology is a real-time communication enabler that allows the sender of the message and the receiver to adapt their response at any given time. In future work, we would like to study user behaviour considering a more sophisticated driver profiling and contextual model, possibly based on semantic ontologies. Determining users' tastes and needs (profiling and classifying them) may help in identifying the products that users need before designing the sale of that product. In other words, by first stimulating demand and then by designing supply. It would, therefore, not be a question of selling products, but of satisfying the needs of individuals.

Before finishing, it is important to indicate the limitations of the research work presented. Age or gender can be two factors that can condition the results and those variables have not been considered, as well as the driving style (the more aggressive the higher the fuel consumption, for example). The socio-economic context of the survey participants has not been considered either. The number of people who have participated in the survey samples, although significant could be considered small to generalise the findings. Furthermore, we reckon that the normalisation process with the expenses data may lead to an average bias as we translated continuous values into concrete scalars for all the respondents. All these limitations must be considered and included in a subsequent analysis process to delve deeper into the study that is now being presented. Still, we believe that the depth of this study has been sufficient to be able to assert that instrumenting cars with technology can result in reduction of car maintenance and usage expenses, with important side-effects towards reducing accidents or pollution.

6. Conclusion

In this paper we have analysed the role that the emerging technology such as IoT can play in the expenses that drivers usually undergo throughout the year, finding that warnings and alerts issued from that technology help to lower the money spent in the car maintenance. To obtain this result, a two stages methodology was used. On one hand, we run a Delphi approach with 25 experts in the car field to understand the main determinants for car expenses. In this initial stage of the exploratory research, we found that technology has a salient role outperforming, according to experts' criteria, other methods such as proximity to point of sale or marketing campaigns. On the other hand, to confirm that experts were right, we delivered a survey to two population samples: people with assistive technology in their cars and people with conventional cars without such ICT asset built-in reaching more than 500 people in total. The results from that survey showed that drivers with IoT devices embedded in their cars spend significantly less money in car maintenance (i.e., petrol, insurance, maintenance, car service, garage, tolls, penalties, taxes and repair costs) than drivers without any kind of assistive technology. Moreover, there are signs that emerging technologies in the car can provide more confidence and knowledge to the drivers about the overall car expenses around the year. Thus, people are savvier or more aware about the money the spent in the car in a yearly basis.

The introduction of all these technologies will suppose and impact to transform the traffic in our cities, increasing the safety, improving the smart mobility and reducing the costs of the transportation.

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Appendix I

Driver survey questions

SEC 1	***Vehicle data***
Q1	What is the brand of your vehicle?
Q2	What year is your vehicle?
Q3	How long have you had your vehicle?
Q4	How many kilometres do you drive per year in your vehicle?
SEC 2	***Mobility and consumption data***
Q1	How much money do you spend per month on Petrol
Q2	How much money do you spend per year on insurance for your main vehicle?
Q3	How much money do you spend per year on maintenance to your vehicle (change of oil, filters, tyres and other incidentals)?
Q4	How much money do you think you spend per year on your vehicle (including petrol, insurance, taxes, repairs, maintenance, parking, tolls, fines, etc.)?
Q5	How much money do you think could be saved per year through a recommendation IT embedded system?
Q6	How much money do you think you could save per year on your vehicle expenses by using a recommendation system based on real needs at any given time?
SEC 3	***Perception of vehicle expenses***
Q1	What percentage of the household expenses is used for vehicle expenses?
Q2	Do you often use promotions or special offers to try to save money on vehicle expenses?

CAPITULO 5: La Geolocalización como guía para el análisis de riesgo en la conducción

5.1 Introducción al artículo científico y principales contribuciones

Finalmente, el capítulo que se presenta a continuación describe el diseño y desarrollo de un clasificador de un modelo de aprendizaje supervisado de *Machine Learning* para estimar el perfil de riesgo asegurador en función de los lugares visitados por un conductor. Esta descripción además pretende dar respuesta a la sub-hipótesis SH4. Dicha sub-hipótesis reza la siguiente descripción: El patrón de movilidad de un conductor permite determinar su perfil de riesgo siniestral y por tanto permite optimizar el precio que una aseguradora ofrece a su cliente.

En este artículo, además, se desarrolla un clasificador de riesgo en función del estilo de vida de un conductor y este método se basó en geoposicionamiento, específicamente en los lugares visitados y frecuentados por un usuario.

El objetivo principal de la publicación indexada asociada a este capítulo se basó en comparar el clasificador tradicional que utilizan a día de hoy las compañías aseguradoras de autos en España llamado SINCO con un clasificador propio desarrollado en base a los lugares visitados por el conductor. El modelo tradicional de análisis de siniestralidad propio de las aseguradoras de autos está basado en un cuestionario que los clientes deben responder. Si los vehículos de los usuarios cuentan con tecnología embarcada en los autos, las aseguradoras están optando por desarrollar el modelo de analizar el estilo de conducción, la velocidad de conducción en función del tipo de vía, el número de kilómetros y otras variables relacionadas con la conducción. Este artículo científico quiso dar un paso más y se planteó un clasificador que permitiera evaluar a los conductores en función de los lugares visitados. De esta manera, el conductor con una vida más apacible debía dar algunos previsiblemente resultados más favorables frente al conductor con una vida menos apacible, siempre en términos de movilidad.

A más detalle, este capítulo y su correspondiente artículo indexado mide el impacto que tiene la aplicación de un modelo de análisis del comportamiento del conductor a través de los lugares que visita. Esta información se utiliza para desarrollar un sistema de precios y aplicar la prima de seguro que más se ajusta a cada cliente de manera particular.

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5.2 Using geolocation data, POIs and drivers' behavioral information to infer risk profiles in future mobility scenarios

Using geolocation data, POIs and drivers' behavioral information to infer risk profiles in future mobility scenarios

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Abstract

The development of new technology-based products has enabled the insurance world to offer new tools that grant a certain level of control over the driver and the services associated with mobility. Analysing driver behaviour through objective data in the connected car offers a plethora of opportunities to model the way someone drives and the services that can be offered accordingly. In this sense, this paper analyses the development of a risk evaluation and management system empowered with drivers' geolocation data and their Points of Interests (POIs) visited, compared with prior drivers' behaviour profiling schemes based on historical claims. For that, this paper compares several supervised classifiers' approaches trained with 40,500 instances of drivers' data obtained from the Spanish Historical File of Automobile accident rate database (SINCO). Our results show that an SVM-based classifier outperforms other alternative models in terms of accuracy. Thus, a novel customer risk analysis model based on their geo-localization and visited locations (POIs) is presented. The results and implications of the new model based on drivers' lifestyle rather than driving-style for driver's health and environmental impact are assessed in the paper.

Key Words

Driving behaviour, Pay As You Drive (PAYD), geolocation, Points of Interest (POI), Usage Based Insurance (UBI), supervised learning.

1. Introduction

In many sectors, digital transformation is having a profound impact on companies' operations. Consequently, technology is evolving in companies from an enabler to achieve higher performance to being at the very basis of its core business. The increase in technology development, the globalization of markets and the economies are deeply changing the environment on which companies operate. This changing landscape in companies is proof of the progressive adherence to IT, telecom and even robotics nowadays.

The automotive industry has taken a significant leap forward thanks to the new commercial opportunities that arise from data generated by end users themselves. During the last years, continuous technological advances have enabled companies to capture and gain insights from a vast pool of data. New technologies have enabled new faster and cheaper ways to treat massive data. These technologies, together with their uses, is called the 'Big Data Revolution' (Kitchin, 2018). This is, as well, revolutionizing the automotive industry and, as a side effect, insurance companies are also taking advantage of this trend on this trend. By analysing these technological advances, there are three major factors that have influenced them in a remarkable way: i) technology permits to capture data that, to some extent, was unimaginable some years ago (i.e. smartphone data or IoT – Internet of Things sensor data from -Smart Cities); ii) communication systems, being these increasingly faster and cheaper, boosting data transmission business development (i.e. Wi-Fi access at malls or the emergence of 5G); and iii) the increasing ability that to store, manage and process huge amounts of data, in real time at an affordable cost (i.e. cloud computing).

All these breakthroughs have enabled the development of new data-grounded models in different economic sectors; the world of mobility not being an exception. Drive insurance companies have thus developed risk evaluation models based on mobility data from their customers (Jin et al. 2018). However, further developments in data analytics may allow us to analyse risk factors from any user with data collected in real time. Out of these factors and new data sources, new models have been developed to improve the insurance price factor based on the driver's behaviour (Huang and Meng 2019). That is, the frequency and type of usage that it is given to a vehicle. In the insurance world, risk premium is gauged based upon two parameters: frequency and cost of claims. The former refers to the exposition and the latter to the amount an insurance agent should pay, as an average, to compensate a claim. Therefore, if the usage frequency or cost of claims could be reduced, the risk premium could also be decremented. The associated data analytics processes can also be used to make driving systems more efficient from the point of view of the emission of pollutants ((Anagnostopoulou et al. 2018). Improved driving behaviour will result in greater safety for the user (Bian et al. 2018), other road users and above all an improvement in vehicle emissions (Paraschivoiu, Meschtscherjakov, and Tscheligi 2019)

Our research hypothesis states that the analysis of the mobility patterns of a car insurance users, through the monitoring of their mobility patterns associated to their lifestyle, allows assigning more effectively their risk profile and, thus, optimizing the price that the insurance company should set for them without the need to resort to classic driving style variables. For that, in this paper, the impact that technology has in the world of car insurance is therefore analysed. More specifically, this work measures the impact that applying a driver behaviour analysis model to the collected data may have on the insurance rate. Therefore, this work described the design and development of a supervised machine learning classifier to estimate the insurance risk profile using vehicle geolocation data, as well as other mobility variables (Husnjak et al. 2015). This work differs from previous proposals in that it applies supervised machine learning models to identify new correlations based on drivers' lifestyle, inferred from the temporal and spatial correlation of visited Point Of Interest (POIs), rather than driving-style.

Indeed, in this work the life-style vector of each driver is configured as the set of all POIs visited and the frequency of each visit. This allows to classify drivers according to some pre-defined categories of drivers, e.g. those belonging to "family type" usage of the vehicle (e.g. Children transport to school, drives to work on weekdays and trips to countryside on weekends) or those linked to "bachelor type" usage (e.g. Drives to work and drives to restaurants and bars at night). These categories have been defined on the basis of a database shared by insurance companies in Spain, which ranks and classifies good and bad drivers based on the years they have been with the same insurance company and the claims they have had during the same period. Our classifier, through a supervised model of artificial intelligence, is going to replace that database with a model which takes into account the lifestyle of a good and bad driver, measured in terms of places visited and frequency of these visits. In other words, when the insurance database says a driver is good, our classifier knows what kind of places he visits. Accordingly, given somebody else profile of visits or visited, we will be able to classify whether that person is a good driver or not.

The structure of the paper is as follows. Section 2 is dedicated to the analysis of the state of the art, where different factors to know the risk profile of a car insurance policyholder through technology application are explored. Section 3 included info about accident rate calculations and section 4 describes the methodology used to analyse data coming from a representative sample of drivers. Sections 5 presents the results of such analysis. Finally, section 6 drives some conclusions and describes some further future research work.

2. Background and Literature Review

In recent years, some insurance companies have already applied data capture models through telematic systems embedded in the car. This technology has allowed them to capture data such as speed, number of kilometres travelled, type of road used, frequency, time schedules and so on. With these new types of data, risk models have been tailor-made according to the individual´s financial scoring (Sadatrasoul et al. 2013). These new models, which insurance companies are using, have spread mainly in Europe and the USA. With this background in mind, this section reviews the existing body of literature regarding the calculation of risk variables within the world of car insurance. More specifically, it analyses the literature on Driving Behaviour (DB) and the so-called Usage Based Insurance (UBI), which have developed models based on the use of the car, i.e. driving behaviour, also known as Pay As You Drive (PAYD). These drivers behaviour models are usually supported by driving-based vehicle data including vehicle speed, engine RPM, throttle position, engine load and many other parameters (Chen, Pan, and Lu 2015). Other times, insurance companies are starting to introduce discount models based on usage and monitoring the type of car usage (Liu et al. 2017). But, it has not been identified in previous related work an approach that links a driver´s risk based on the POI that s/he visits and the frequency with which s/he visits them, as this paper describes.

In the world of insurance, the use of technology is directly linked to the factor of accident reduction (Dijksterhuis et al. 2016). This use of technology has not always been stressed in the same way. Anyhow, this literature review brings about that most risk analysis models are focused on studying the price element as a function of frequency of car use and the way the car is being used (Roel, Antonio, and Claeskens 2017). This paves the way for considering user´s profiling based on the location points visited (geolocation through GPS) and the frequency in which these points have been visited.

Previous work has already explored how car data could drive into personalized driver risk assessment to adequate individualized insurance rates (Gerpott and Berg 2013). Still, current insurance companies generally do not have a way of personalizing the risk and, hence, they design insurance premiums based on *a priori* risk data, without considering the current driving information (Parry 2005). However, existing technology does allow to capture vehicle data in order to characterize the driver and, thus, observe his or her accident behaviour and, consequently, adapt the insurance premium to the forecasted risk that the driver portrays against the insurer (Handel 2013). The approach followed by this research lies more in making a profile of the user based on the information taken from the points they visit and the frequency in which such points are visited, rather than using the typical variables of risk analysis (speed and frequency of car use).

According to (Desyllas and Sako 2013), PAYD is a novel method of determining insurance premiums on the basis of when and how a car is driven. Insurance companies could improve their billing methods by aligning individual risks with the individual pricing (Husnjak et al. 2015). The main idea is that instead of a fixed price, drivers have to pay a premium based on their driving behaviour, contextualized as a score from 0 to 10, being 0 the worst and 10 the best (Tselentis, Yannis, and Vlahogianni 2016a) driving behaviour. This way of understanding insurance price fixation is interesting and can be carried out thanks to exploiting vehicle location data, but they certainly do not consider analysing the actual places visited nor the frequency with which these places are visited.

Tselentis, Yannis and Vlahogianni (Tselentis, Yannis, and Vlahogianni 2016) argue that the installation of UBI programs at insurance companies would not only help erase driver risks thanks to driving and data analytics but can also motivate drivers to improve their driving behaviour through programs that identify driving improvement areas and better pricing. In this regard, (Guillen et al. 2019) highlight that it is not only important to remind the driver that the less she drives, the smaller probability she has to have an accident. But it is also equally important to emphasize for consumers that improving the driving style could lead the insurance company to lower the fees (Ma et al. 2018). In this sense, if drivers do not have accidents and their behaviour is adequate, according to the insurer, drivers should benefit from reductions in the premium risk fee, even if driving long distances.

The way of capturing data to create PAYD-based insurance models, are normally rooted in two types of data source management. On the one hand, Smartphone (i.e. (Hu et al. 2019); (Osafune et al. 2017); (Handel 2013); (Gerpott and Berg 2013) and, on the other hand, car-connected devices (i.e. (Chen, Pan, and Lu 2015); (Porrini, Fusco, and Magazzino 2020). This work has performed the data collection through an OBD (On Board Diagnostic) device connected to the vehicle.

Introducing driving models of analysis and data collection, may have a component of loss of privacy, to some extent, but in parallel, drivers are attracted by a better price, more appropriate to their profile (Terzi, Tosun, and Sagiroglu 2018).

In this review, it has been identified that Italy seems to be the country with the greatest implementation of telematic systems in the field of automobile insurance. A possible explanation is that a regulation issued in 2012 fostered this movement of on board telematic systems. Out of the 37 million cars in the country, 4,8 million are already equipped with such devices, compared to the 3,3 million of the Americans in the USA or the 0,6 millions in the UK (Porrini, Fusco, and Magazzino 2020). According to this latter article, there is a direct correlation between the use of such systems and the decrease of car accidents and in the price of car insurance policies. This analysis introduces us to the concept that the use of technology has an influence in the frequency of accidents but does not make any reference at all to the objectives of our work which are focused in studying the drivers' risk based on the characterization of the points they visit.

On the other hand, (Carfora et al. 2019) propose the introduction of a model for analysing driver behaviour identification using unsupervised machine learning techniques. (Zhang et al. 2018) introduce the usage of regression algorithms where some driving risk factors are correlated with accidents but once again they do not analyse geo-position information and user characterization analysis based on the information of the frequency of visited points to obtain a user risk profiling model.

Therefore, it can be stated that there is a gap between the object of analysis of this article and the literature reviewed. Based on the inexistence of the following fields: factor analysis models comparing the analysis of a drivers' behaviour, their historical rating by insurers and the definition of the risk profile through an analysis of supervised models. Until now, geolocation is the only variable that defines the user characterization as it is going to be demonstrated in this article.

3. Background on accident rate calculations by car insurance companies

As described in previous sections, this piece of research aims to generate a new classifier to predict the insurance risk profile of a driver in an objective manner. In this case, the risk profile has been defined as a class hierarchy. Specifically, it uses five classes to which any user may belong to. Instead of training for discrete or continuous risk profile values, which would force to use regression methods, every known user is assigned a 'risk class', representing the user's probability of filing claims. The risk profile will be trained against what is called the SINCO (Tirea 2020) score, a database that contains the historical accident rates. SINCO (the Historical File of Automobile Insurance in Spain) allows car insurance companies to calculate the suitable price to assign to each car insurance policy.

SINCO refers to a database containing information on insurance policies and claims associated with them in terms of civil liability (third party damage). Since the emergence of this database, insurance companies have started to share their customers' accident data, specifically those for which the user has been responsible for the past 5 years.

The SINCO file is an initiative of a company called TIREA (Information Technology and Networks for Insurance Entities S. A.)[7], to which almost all insurance companies in Spain are adhered. This file, that reports vehicle claims, allows for immediate access to the driving history of a person who is interested in signing for car insurance.

SINCO aims to bring greater transparency to the motor insurance industry through an objective system so that insurers have a reliable source of information when assessing the risk and, thus, set the policies 'premium.

The following table displays an overview of the SINCO classifier. This classifier is a black box from where the insurance industry obtains results for each driver consultation. It contains data supplied by 95% of the Spanish motor insurance companies. The result of the classifier is identical for every query associated to a concrete driver. Still, each insurance company applies internally some business rules (increasing or decreasing the price of the insurance). That business rules are based on each insurance companies' criteria.

Please note that each insurance company has its own version, but all of them follow the same rationale. The matrix in Table 1 is structured as follows, being 5 years with no claims the best (5/0) and 1 year in a company with 5 claims (1/5), the worst.

Table 1: SINCO Classifier

[7] https://www.tirea.es/Entidades-Aseguradoras/Autos/Sinco/Descripcion.aspx

	SINCO Classifier									
	1		2		3		4		5	
	Years	Claims	Years	Claims	Years	Claims	Years	Claims	Years	Claims
Good		0		0		0		0		0
		1		1		1		1		1
Regular	5	2	4	2	3	2	2	2	1	2
		3		3		3		3		3
Bad		4		4		4		4		4
		5		5		5		5		5

Nº of Years	No. of years with the same insurance company
Nº of Claims	No. of guilty claims with opposite

An example of how claims information is structured is explained below:

1) The information is structured according to two parameters: number of consecutive years a customer has been with the same insurance company and number of accidents he or she has had during that period.
2) For SINCO, the best driver is the one who has stayed for the last 5 years with the same insurance company and has not had any claims.
3) On the other hand, SINCO defines the worst driver as the one who has not even served a year with the same insurance company and has reported 5 accidents in this period.
4) The calculation of the intermediate/average levels (between point 2 and point 3 above) is to be interpreted and applied by each insurance company. However, the standard applied in the industry, generally, is that the more years in a company and the fewer claims, the better the SINCO score is. On the contrary, the fewer years and higher accident rate, the worse the SINCO score will be.

4. Methodology

The methodology used in this paper is based on the use and comparison of supervised models. The idea of the supervised model was to analyze and classify a driver depending on the POI's visited in comparison with the SINCO data base. Similar approaches and systems that have historically been used categorize a driver based on their risk (being this risk calculated through driving criteria: speed, number of km travelled, night or day driving, etc.). However, the presented approach is based on drivers' lifestyle (Point of Interest visited).

4.1. Methodology landscape

The mobility data of each user considered has been collected by the Next Group Company[8] after customers' consent. Specifically, all data used in this study is collected from OBD-II devices (see Figure 2) installed in the driver's vehicle, which send real-time GPS-derived data. The on board OBD device reads data from various sensors that the car has, monitors the status of its various components, sends them to the platform for processing and data analysing (ordered and managed). Generically, this data is called the telemetry of the vehicle (Amouzegar and Patel 2013). The dataset sample that was used for this study was gathered by Spanish drivers with similar social-demographic profile in order to avoid any kind of statistical bias when comparing behaviours. This data is made up of the user's ID, longitude, latitude, vehicle speed, and the data collection time (timestamp) that the OBD-II device sends to the Grupo NEXT servers every 45 seconds. The data coming directly sent from the OBD-II device is called raw data (User ID, latitude, altitude, time set, turn on, turn off, etc.), since it is the primary data obtained from the device. In general, as in this case, it is data that individually, without further processing, does not contain much information. Therefore, its processing is necessary to transform data into 'useful' information.

In mathematical terms, a classification occurs when we have input data (we call them "X" and in our case they are the vectors with mobility data show in Figure 1, one output variable (we call it "Y" and in our case these are the classes from one to six of SINCO database risk analysis) and we use an algorithm to learn the "mapping function" between the input data X and the output variables Y. This function is defined as $Y = f(X)$ and we call it a classifier or supervised predictive model. It is a supervised classifier because the learning process of an algorithm from a set of historical data (the SINCO results for each driver 5 years claims) resembles the human learning process: the algorithm performs predictions iteratively over the historical data and is corrected until optimal performance is achieved.

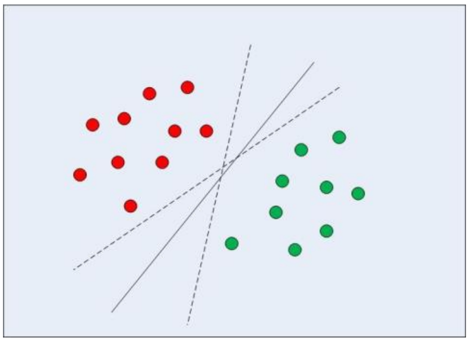

Figure 1. Simple linear classifiers problem

The simplest algorithm to train a classifier consists of a linear function that separates the classes for all dimensions (see Figure 1).

[8] www.gruponext.es and www.nextsmartcar.com

The problem with simple linear classifiers is that, in real cases with many training data, many dimensions, and many classes, many possible solutions are presented with the same error.

The classifiers proposed in this paper were developed using scikit-learn and Tensorflow libraries. Scikit-learn is a machine-learning library for Python (Pedregosa et al., n.d.) while Tensorflow (Abadi et al. 2016) is an open-source machine-learning library optimised for GPU-enabled systems' computations. It is used scikit-learn[9] Principal Components Analysis (PCA) and its different classifier libraries for prototyping and TensorFlow[10] for training and inference because of its speed capabilities.

In order to create and configure the infrastructure needed to capture data, its pre-processing, generate the customer´s characterization and finally the creation of subsequent models, Amazon Web Services (AWS) cloud architecture has been used with the following elements (see figure 2). This infrastructure was created by the company Grupo NEXT[11]

1) **Data capture and pre-processing**- From a request coming from a machine dedicated solely to the execution and monitoring of Python scripts, it is asynchronously, and multi-thread/multi-task initiated. This machine is a T3 type under AWS EC2 cloud computing services. We pre-processed the raw data from the OBS-II device together with those of the insurance partner: the SINCO historical score. We then added an incident and event notification system through AWS using the AWS SNS (Service Notification System) and AWS Cloudwatch[12]. All these are pre-processed with AWS Lambdas, i.e., functions as a service.

2) **Models** - using Keras[13] to control and execute the training in supervised and non-supervised models in Tensorflow and scikit-learn, a cluster of 10 machines with dedicated GPUs has been built and configured.

[9] https://scikit-learn.org/stable/install.html
[10] https://www.tensorflow.org/learn?hl=es-419
[11] www.gruponext.es
[12] https://aws.amazon.com/es/cloudwatch/
[13] https://keras.rstudio.com/

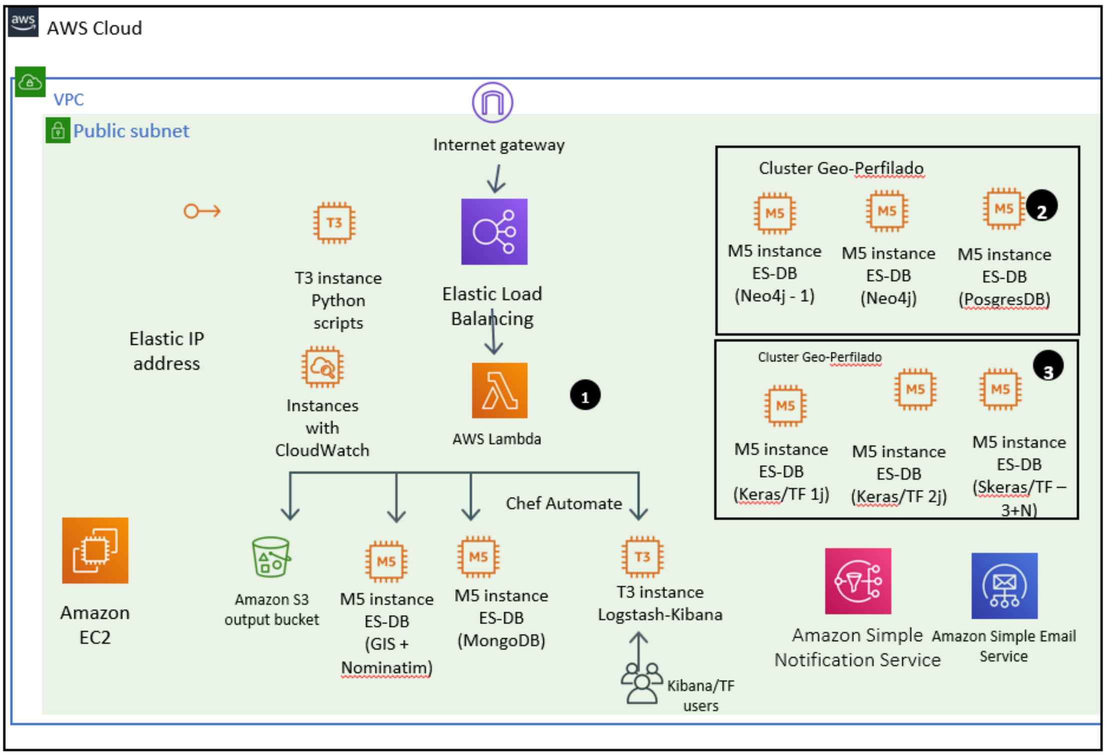

Figure 2. Technical solution architecture

4.2. Supervised Model Implementation

Raw data should not be used directly to train models (whether supervised or unsupervised classifiers). If this was done, what it would get is a classifier that would only be able to distinguish based on a given latitude and longitude or the closest point nearby to that corresponding to each class. For this reason, to obtain data that it can be used to train a classifier, an inference process is necessary. In this case, starting from raw data representing geographic coordinates, we needed to 'find out' which actual place, name it a school, company, store, shopping centre, highway, etc. (also called POI or Points of Interest) is at those coordinates. This process is called *reverse geocoding* (St-Hilaire et al. 2007).

Once the POI of each coordinate is obtained and knowing the timestamp of each user (and the time that remains in each POI as well as the speed of the vehicle), it is possible to infer, with high certainty, the places visited by each user, how often and, based on this, draw subsequent inferences: where they sleep, where they work, where they do the weekly shopping, which sports centre they visit, or which leisure places they frequent.

Due to the nature of raw data (which is based on vehicle mobility data and not on the user) it encountered a problem when making the inference of which points of interest were visited by the user: It would be known where the vehicle was, but not the user.

To solve this problem and obtain the highest degree of confidence when assigning a POI to a user, it has been worked on various hypotheses based on the different POIs near the vehicle's parking place. For example, if a parked vehicle is 10 meters from 5 different stores, it would be assigned a low probability (0.01) to the potential visit of the user to each POI, since it cannot be inferred a visit to one store compared to another. If this driver visit this or a similar POI again, them the probability assigned is high. In another example, it has been introduced the hypothesis that the recurring parking of a vehicle during working hours indicates the user's workplace, or the recurring parking of the vehicle during night hours the usual residence.

To obtain the data corresponding to each POI, it is necessary to use georeferenced databases, which provide us with the POI category (e.g., School, business, hospital, etc.) and within each category, the corresponding sub-categories (e.g., primary school, electronics' trade, children's hospital, etc.). This classification by categories and subcategories is called a taxonomy and each individual category. In our case we used a mix of Open Street Maps[14] (OSM) and Google Maps[15] taxonomies.

The process of selecting the data (dimensions or variables) and relationships in a user's characterization, it is called 'dimensionality reduction'. If N is the number of dimensions or variables that we have obtained for the user, in our case it will be all the different categories of POIs, in addition to the set of all possible relationships (we call it R) between them and the user (the relationships of the characterization). The real number of possible dimensions will be the Cartesian product of N x R. In our case it has been an N of 10,200 (number of taxon and an R of 1,100 (total of possible relationships defined in the characterization), then N (the overall dimensions) will be 11,220,000.

If M is the number of users with data and Y results (understood results as a SINCO class of the history and Y the 'true' observations of the function Y = f (x) that we saw previously), it leads us to the maximum number of users with useful observations to train a supervised model will be, in our case, 40,500 (the number of common users).

The problem we encounter is that (mathematical proof aside), when N is much greater than M (N >> M), any supervised classifier that is trained by any algorithm will result in unstable models with low performance (the called the 'curse of dimensionality'. So, we need M to be much greater than N (M >> N). Even if we eliminate the Rs (that is, we assume that in the characterization all relations are of the type "the user is interested in a certain POI category"), we would still have an N of 10,200 and M of 40,500. The only option is to reduce N to those dimensions that contain more discriminatory information between the different classes.

Out of the dimensionality reduction techniques, the most developed one and with the best results for the type of data we have, is the PCA (Principal Component Analysis) (Jolliffe 2002). This process is applied to all variables and in order to obtain a new reduced data set of 100 dimensions, which

[14] https://planet.openstreetmap.org
[15] https://developers.google.com/places/supported_types

we reduced until classifiers' precisions stopped improving. The resulting data sets are the ones properly to train the supervised models.

The PCA technique consists of extracting the normal values out of all the observations and all the dimensions, in such a way that when sorting them from highest to lowest, it is obtained for each dimension the 'information provided by each dimension in the discrimination of each class'. Now we only need to select which of these will be the ones it will be used to train our supervised classifier. There are 2 techniques. One is to select the dimensions manually by an expert when the domain gives rise to it (not in our case, since it is difficult to know which dimensions of a characterization are important for SINCO beforehand). The second is automating it by generating several supervised models using sets of them (30, 40, 50… up to 100 sets of dimensions and having them compete with each other to obtain the optimal number of dimensions). The resulting precision for each classifier, each with a different number of dimensions, decided the best performing set of dimensions.

This is the process with the highest computational cost, since the number of models that compete with each other will ideally be formed by the Cartesian product of the size of the set of selected variables (the set T of sets 30, 31, 32, ... up to N '' / 2) and the number of possible dimensions (10,200). In order to avoid a computationally unmanageable number of classifiers, it has been decided to reduce the number of sets to 150 experiments.

Once we obtain a trained classifier, it must be able to test it with users who have not been used in the training process. To do this, the first thing to focus on is the creation of a subset with the N data, we call it N', which consists of 33% of the users with SINCO data. This is our test data set for each model generated. This causes N to be reduced (from 40,500 to 30,000) and N ” from 10,500. A total of 900 computing hours have been conducted to date (in 53 uninterrupted days) for data processing and generation of supervised models.

In Figure 3, the process of data curation and analysis is presented.

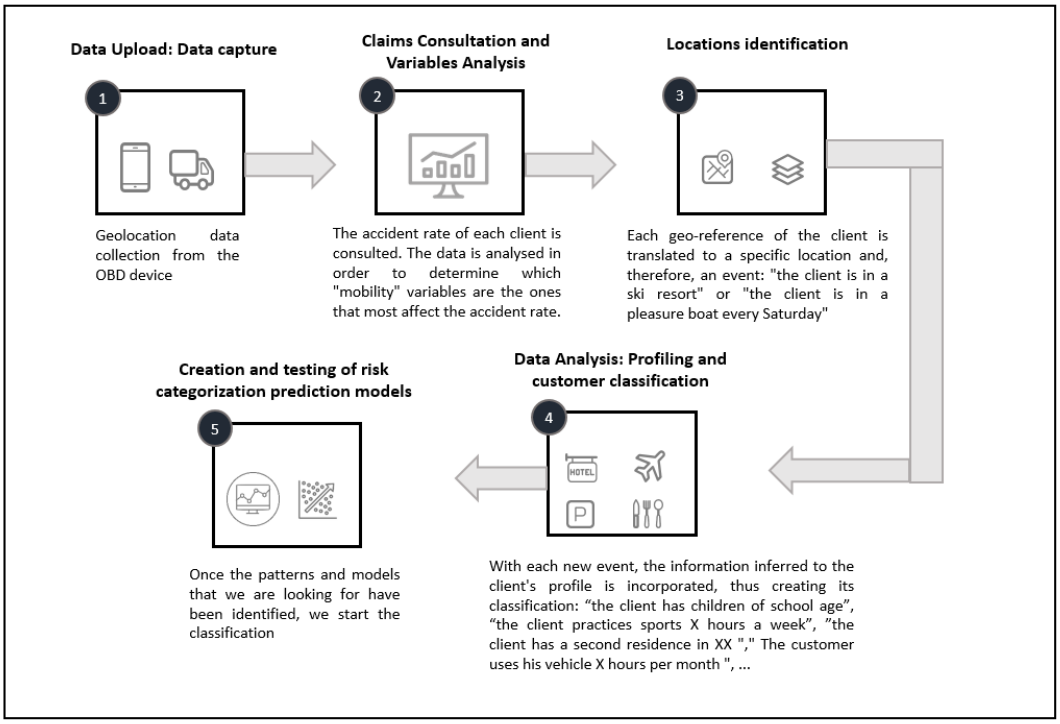

Figure 3. Data curation and analysis

4.3. Example

As shown in Figure 4 through three samples, at the end of the presented process, each user from the dataset is defined by the data supplied by their connected vehicle with at least 3 months of data and 1 event per week (vehicle movement of more than 5 km). Each POI event means that a vehicle has visited a place or location for at least 5 minutes. All POIs are part of OSMs categorization. SINCO score is represented by the dimension 'Score' on each of the users' vectors.

All the vehicles that have served as the basis for this research are vehicles with on-board technology. As an example of how the classifier works, the following can be noted: The first thing that is done is the classification of a driver based on SINCO. This database, as already explained, is a black box that is being used by 95% of the insurance market in Spain in order to sort drivers. This study stressed the fact that once the result of the SINCO classifier is obtained, it is developed a supervised data analysis model to see how, depending on the places and frequencies visited, it is been able to translate the SINCO classifier into a POI classifier. In this way, if SINCO indicates that a driver is good (remember that for SINCO a good driver is a 5/0), our supervised model will indicate which factors of visits and frequencies should be taken into account (see Figure 4 to understand the values of 3 users that have been taken as an example). Being this said, it can be observed that when SINCO indicates that a driver is rated good, all drivers who have the same behavior (in terms of similar places visited with similar frequency of visits) will be classified as good drivers as well. Normally the POI's classifier that has been used through the supervised methodology indicates that the good drivers that SINCO classifies as such, have a peaceful life (frequent sports venues, churches, quiet restaurants) and those that SINCO classifies as worst drivers, have a more disordered life (have more nightlife than day life, visit pubs and discotheques and do not generally visit sport centres).

USER 1: bakery,3 fuel,4 greengrocer,1 insurance,1 locality,60 memorial,2 motorway,2 pedestrian,1 pharmacy,368 place_of_worship,1 residential,3481 restaurant,2 secondary,1595 square,4 supermarket,224 track,10 trunk,3 yes,2 Score,2 tags, bakery,3 fuel,4 greengrocer,1 insurance,1 locality,60 memorial,2 motorway,2 pedestrian,1 pharmacy,368 place_of_worship,1 residential,3481 restaurant,2 secondary,1595 square,4 supermarket,224 track,10 trunk,3 yes,2 Score,2 "

USER 2: administrative,3 bar,8 community_centre,1 fuel,2 hospital,60 industrial,4 locality,48 mall,20 pharmacy,487 pitch,62 primary,29 pub,1 residential,663 restaurant,234 school,116 secondary,58 sports_centre,7 tertiary,1780 townhall,4 track,1 unclassified,20 yes,401 Score,2 tags, administrative,3 bar,8 community_centre,1 fuel,2 hospital,60 industrial,4 locality,48 mall,20 pharmacy,487 pitch,62 primary,29 pub,1 residential,663 restaurant,234 school,116 secondary,58 sports_centre,7 tertiary,1780 townhall,4 track,1 unclassified,20 yes,401 Score,2

USER 3: apartment,1 bank,5 camp_site,1176 car,1 caravan_site,37 computer,1 drinking_water,2 fitness_centre,3 footway,3 fuel,619 hotel,612 house,1 jewelry,1 primary,632 residential,7974 restaurant,437 school,2 secondary,1 service,1 sports,1 sports_centre,1 square,2 supermarket,1648 tertiary,819 unclassified,969 university,934 wood,950 Score,1 tags, apartment,1 bank,5 camp_site,1176 car,1 caravan_site,37 computer,1 drinking_water,2 fitness_centre,3 footway,3 fuel,619 hotel,612 house,1 jewelry,1 primary,632 residential,7974 restaurant,437 school,2 secondary,1 service,1 sports,1 sports_centre,1 square,2 supermarket,1648 tertiary,819 unclassified,969 university,934 wood,950 Score,3

Figure 4. Example of first 3 users' vectors representing how many times each user has visited an OSM-based POI. Each user has at least 3 months of vehicle data.

5. Results

The results of the classifier on the test data, can then be clustered as follows:

- True Positives (TP): when the real class of the data point was 1 (True) and the predicted class is also 1 (True)
- True Negatives (TN): when the actual class of the data point was 0 (False) and the predicted class is also 0 (False).
- False Positives (FP): when the actual class of the data point was 0 (False) and the predicted one is 1 (True).
- False Negatives (FN): When the actual class of the data point was 1 (True) and the predicted value is 0 (False).

The extraction of 'blind' customers for independent evaluation – 9,000 blind customers have been drawn (with whom no training nor internal evaluation in any model have been carried out) out of the 40,500 common customers (from Grupo Next).

Out of the 38 models generated during the last cycle, the best one has a precision of 92.6% and a Recall of 74.1% and F-Score of 0.823 (see figure 5):

- **Precision (P):** What proportion of positive identifications have really been correct = TP / (TP + FP): **0.92627599**
- **Recall (R):** What proportion of real positives has been correctly identified = TP / (TP + FN): **0.74186223**
- **F-Score:** It is the measure of precision that a test has = 2 * P * R / (P + R): **0.82387558**

TP 8820	FP 702
FN 3069	

Figure 5. Metrics results

In addition, the different classifiers have been compared with their results being provided in Figure 6. It has been concluded that the SVM is the one with best accuracy when comparing it with other classical classifiers: LR (Logistic Regression), LDA (Linear Discriminant Analysis), KNN (K-Nearest neighbours), CART (Decision Trees), NB (Naive Bayes) and MLP (Multi-layer Perceptron). The main features and characteristics of these tested classifiers are explained in the Appendix 1 for the sake of clarity

Classifier	Accuracy	Standard Deviation (Accuracy)
LR	0.677442	0.028610
LDA	0.618178	0.043115
KNN	0.682193	0.034280
CART	0.606804	0.020185
NB	0.421949	0.043726
SVM	0.746817	0.045141
NN (MLPC)	0.671421	0.038335

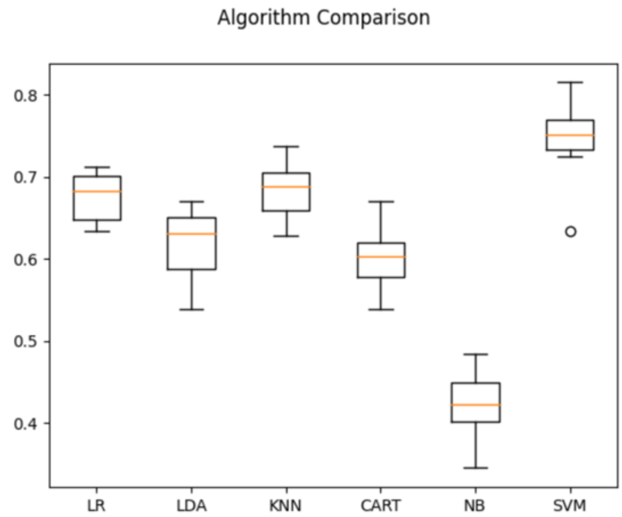

Figure 6. Accuracy and its standard deviations for the six compared classifiers: Logistic regression (LR), Linear Discriminant Analysis (LDA), K-nearest neighbours (KNN), Decision Trees (CART), Naive Bayes (NB) and Support Vector Machines (SVM) and Multi-layer perceptron classifier (NN)

The best accuracy was achieved using a SVM classifier with a non-linear radial-basis function-based kernel as shown in Figure 6. Recall that a support vector machine constructs a hyper-plane or set of hyper-planes in a high or infinite dimensional space, which can be used for classification, regression or other tasks. Intuitively, a good separation is achieved by the hyper-plane that has the largest distance to the nearest training data points of any class (so-called functional margin), since in general the larger the margin the lower the generalization error of the classifier. SVMs seek the separation of the classes by maximizing the margin between the data closest to each other of each class (the 'support vectors') and applying these a nonlinear function that affects the entire class to which the support vector belongs. It was founded that the results of the SVM classifier together with the kernel using a Radial Basis Function (RBF) performed the best as can be seen in Figure 6.

6. Conclusions

Thanks to new data collection and management techniques, insurance premiums have succumbed to the technological revolution. Until now, the concept of the car insurance price was based, according to what it already has to put forward, on two main premises: a) the frequency of use of the car; and b) the historical accident rate that has been gathered in all the pool of data that insurance companies share. Now with technology embedded in the car, the former data would be enriched with the way the car is used and the locations drivers visit.

This work has described how it has been moved beyond traditional insurance policies proving that geolocation management allows us to characterize and give value in terms of scoring to each user of an insurance company. The locations (point of interest) have been gauged and translated them into a risk level. To be more precise, what has been done in this research was to define the SINCO profile of each user and compare this classification with the type of driving of a user based on the places that they have visited. This risk level which has been presented in this piece of research has an accuracy of 74%. It can therefore state that this user characterisation model offers an additional and complementary method to every other method that exists to date (i.e. not only the traditional factors of car insurance based on speed, frequency of use and other elements of car control are the only ones that can be used.).

The POI's level (restaurants, shops, bars, hospitals, office building, etc.) that it has been highlighted in the results of this research allows us to conclude that there is a correlation between the accident rate (claims) and the locations that they visit. This conclusion should help to improve and optimize the way an insurance company calculates its prices, because the insurance companies don't need to consult back again the SINCO data base and pay for it.

Besides, it is argued that the approach used in the present paper opens the door to future research studies where the reference of the analysis of the user characterization can contribute a great value, as has been shown in this study. Of course, this methodology can be applied to all other insurance activities, but also to other activities, such as a system that allows you to complement the financial scoring of a client or a scoring to analyse the behaviour of a client to whom you are about to rent a house, to name but just a few. This article may provide a guide for future research works that aim to draw a classification of a set of people. The way in which a user is characterized opens up new scenarios for other areas of insurance to use this classification. It will allow, for instance, to define whether a user of a health insurance company visits sports centres, leisure centres or has a more sedentary profile. Furthermore, although this was not the main focus of this work, this is indeed an area where drivers' behaviour cannot only be made more secure but also more sensitive to the environmental footprint.

In future work, there are different areas where we must continue to experiment as (i) create inferred non-independent dimensions based on semantic reasoning, (ii) include the temporal dimension on the data such as night vs day in order to discard POIs which are closed and other temporal-based rules (iii) should be explored, such as vacation periods or Covid-19 related restrictions.

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Appendix

LR (Logistic Regression) – Logistic regression, despite its name, is a linear model for classification rather than regression. Logistic regression is also known in the literature as logic regression, maximum-entropy classification (MaxEnt) or the log-linear classifier. In this model, the probabilities describing the possible outcomes of a single trial are modelled using a logistic function.

LDA (Linear Discriminant Analysis) - A classifier with a linear decision boundary, generated by fitting class conditional densities to the data and using Bayes' rule. The model fits a Gaussian density to each class, if all classes share the same covariance matrix.

KNN (K-Nearest neighbours) - Neighbours-based classification is a type of instance-based learning or non-generalizing learning: it does not attempt to construct a general internal model, but simply stores instances of the training data. Classification is computed from a simple majority vote of the nearest neighbours of each point: a query point is assigned the data class which has the most representatives within the nearest neighbours of the point.

Decision Trees - are a non-parametric supervised learning method used for classification. The goal is to create a model that predicts the value of a target variable by learning simple decision rules inferred from the data features. A tree be a piecewise constant approximation.

Naive Bayes– Naive Bayes methods are a set of supervised learning algorithms based on applying Bayes' theorem with the "naive" assumption of conditional independence between every pair of features given the value of the class variable. Bayes' theorem states the following relationship, given class variable y and dependent feature vector x1 through xn, :

$P(y|x_1,\dots,x_n)=P(y)P(x_1,\dots,x_n|y)P(x_1,\dots,x_n)$

Using the naive conditional independence assumption that

$P(x_i|y,x_1,\dots,x_{i-1},x_{i+1},\dots,x_n)=P(x_i|y)$,

for all i, this relationship is simplified to

$P(y|x_1,\dots,x_n)=P(y)\prod_{i=1}^{n}P(x_i|y)P(x_1,\dots,x_n)$

Since $P(x_1,\dots,x_n)$ is constant given the input, we can use the following classification rule:

$P(y|x_1,\dots,x_n)\propto P(y)\prod_{i=1}^{n}P(x_i|y)\Downarrow\hat{y}=\arg\max_y P(y)\prod_{i=1}^{n}P(x_i|y)$,

and we can use Maximum A Posteriori (MAP) estimation to estimate P(y) and $P(x_i|y)$; the former is then the relative frequency of class y in the training set.

The different naive Bayes classifiers differ mainly by the assumptions they make regarding the distribution of $P(x_i|y)$.

In the case of our research, it has been used a Gaussian Naive Bayes classifier. The likelihood of the features is assumed to be Gaussian:

$P(x_i|y)=12\pi\sigma_y2\exp(-(x_i-\mu_y)22\sigma_y2)$

The parameters σ_y and μ_y are estimated using maximum likelihood.

Multi-layer Perceptron (MLP) - is a supervised learning algorithm that learns a function $f(\cdot):R^m \rightarrow R^o$ by training on a dataset, where m is the number of dimensions for input and o is the number of dimensions for output. Given a set of features $X=x_1,x_2,...,x_m$ and a target y, it can learn a non-linear function approximation for either classification or regression. It is different from logistic regression, in that between the input and the output layer, there can be one or more non-linear layers, called hidden layers.

CAPITULO 6: Discusión y conclusiones

6.1 Contribuciones de la tesis

En la actualidad, y tras una revisión exhaustiva del estado de la cuestión, el autor de esta tesis doctoral declara que no existen evidencias suficientes sobre el impacto de la tecnología en el ámbito de la movilidad desde el punto de vista del uso de las tecnologías para reducir los gastos alrededor del mantenimiento vehículo. En la literatura existente, difícilmente se han encontrado referencias que evidencien un análisis como el propuesto en esta tesis.

Este sentido, esta tesis doctoral aporta las siguientes tres contribuciones científico-tecnológicas que pueden ser aplicadas al mundo industrial asegurando el impacto y la transferencia que se espera de una tesis en colaboración con empresa:

1) **MODELOS DE ADAPTACIÓN TECNOLÓGICA**. Un modelo que puede ser utilizado para implementar soluciones tecnológicas (desarrollo de web o apps móviles) alrededor del mundo del automóvil, que tiene en cuenta, además, los principios de persuasión del uso de la tecnología que más impacto tienen en los conductores. El capítulo 3 se corresponde a un artículo indexado que muestra los principales principios de la persuasión tecnológica en el mundo de la movilidad que de implementarlos pueden dar lugar a conseguir más estímulos y respuestas de los conductores con el foco puesto en reducir los costes de la conducción. Para ello incluso se presenta un diseño con una tabla (Ver tabla 5 del capítulo 3) que el lector puede aplicar directamente.

2) **LA TECNOLOGIA COMO MOTOR DE REDUCCIÓN DEL GASTO DE LA MOVILIDAD.** Por otra parte, esta tesis contribuye mostrando el papel que juega la tecnología embarcada en un vehículo para reducir los gastos corrientes del automóvil. Hasta la fecha se había analizado el papel que podía jugar la tecnología embarcada en un vehículo desde el punto de vista del control, seguridad, mantenimiento y gestión de un vehículo. Esta tesis da un paso más allá contribuyendo con datos en los que se muestra la evidencia del valor que tiene la tecnología para reducir los gastos que ocasiona un vehículo automóvil. Esta aportación, además, viene primero refrendada por la opinión de un grupo de expertos en distintos campos de conocimientos y, posteriormente, confirmada por un análisis estadístico donde se pudo apreciar la diferencia entre el gasto que ocasiona un vehículo conectado frente a otro que no lo es. Este impacto está cifrado en un ahorro medio de 180€ por vehículo y año. En un país como España y tomando los 24 millones de turismos existentes en el parque español podemos concluir con que el impacto de la tecnología permitiría

ahorrar 4,3 billones de euros al año. Este análisis pretendía demostrar que los vehículos conectados tienen la capacidad de reducir los gastos del vehículo frente a los vehículos no conectados.

3) **MODELO DE CLASIFICACIÓN DE RIESGOS DE CONDUCTORES A TRAVÉS DE LA GEOLOCALIZACIÓN** Adicionalmente, la tesis aporta un modelo nuevo de clasificador de conductores de vehículos para estimar el perfil de riesgo asegurador utilizando la geolocalización del coche. Hasta la fecha, ha operado en España un modelo de clasificador de conductores que basa su metodología en los datos históricos acumulados de siniestros con contrario. En el modelo que se presenta en esta tesis, la propuesta de valor pasa por valorar el estilo de vida de un conductor en función de los lugares que frecuenta, el tiempo que pasa en cada lugar, la hora del día, el día de la semana y el resto de los atributos para completar un modelo que va a permitir al mundo asegurador disponer de otro modelo de evaluación del riesgo de un conductor. El modelo que se ha presentado cuenta además con una ventaja respecto al modelo tradicional que se venía utilizando en nuestro país. Esta ventaja reside en que una vez se implementa este modelo en una empresa, no requiere de inversión adicional en la consulta de bases de datos sino en el desarrollo de un motor de análisis de conductores que alimenta los modelos supervisados de *machine learning* utilizados en este trabajo.

6.2 Validación de las hipótesis

Los anteriores capítulos han ido estableciendo el marco de la investigación objeto de la presente tesis. La validación de las hipótesis que formulamos en el capítulo 1, sección 1.2, es efectuada en este apartado.

La primera sub-hipótesis (SH1) expresaba lo siguiente "*Los conductores son receptivos a utilizar un dispositivo/artefacto para recoger información del coche que les pueda brindar beneficios*". Esta tesis se ha desarrollado investigando el uso y la utilidad de la tecnología embarcada en vehículo frente a vehículos convencionales sin tecnología a bordo. Basados en el estudio del primer artículo científico, reportado en el Capítulo 3, podemos afirmar que no sólo las personas están dispuestas a aceptar el uso de un artefacto de tecnología en su vehículo, sino que además también aceptan la provisión de estímulos a través de interfaces persuasivas. Estas afirmaciones fueron validadas a través de una encuesta, done interrogamos a conductores de vehículos con tecnología embarcada sobre las estrategias de persuasión que creen que mejor encajan en este tipo de sistemas embarcados. Además de preguntar a los usuarios sobre la utilidad de la tecnología también se les preguntaba por aquello que les parecía más y menos útil. En este sentido, los conductores indicaron que la tecnología que les permite autogestionar sus datos, personalizar los mensajes que se le envían, ofrecer recordatorios y sugerencias, son las acciones que más valoran los conductores de vehículos conectados frente a aquellas que les compara con otros y no ofrece información tan personal ni tan adaptada al usuario.

La segunda sub-hipótesis (SH2) hace referencia a "*Los principios de persuasión que más encajan en la tecnología embarcada son los que más relación tienen con la reducción de los gastos del vehículo*". Tal y como vimos en el capítulo 3 de la presente tesis, los principios de persuasión que más afectan al conductor son aquellos que más relacionados están con el control del gasto. Esta tesis contribuye en el sentido de ayudar al lector a identificar cuáles son esos principios y cómo se pueden utilizar para conseguir un impacto mayor en los usuarios.

La tercera sub-hipótesis (SH3) se refiere a que "*los conductores que utilizan tecnología a bordo, son capaces de reducir el coste anual en torno a la movilidad de su vehículo*". En el segundo artículo que se presenta en esta tesis (capítulo 4) se confirma que el coste por kilómetro se reduce en 0,012 euros. Para un promedio de conducción de 15.000km al año, que es la media de lo que se conduce en nuestro país, el impacto es de 180€ de ahorro al año a favor de los vehículos que utilizan tecnología embargada. Todo ello se presentó comparando las muestras, ambas muy similares para evitar sesgos de ningún tipo y poder precisar el nivel de resultados. La contribución que ayuda a refrendar esta hipótesis se basa precisamente en el análisis cuantitativo del impacto de la reducción de costes en la movilidad.

La cuarta y última sub-hipótesis (SH4) que se planteaba en esta tesis está relacionada con la aplicación práctica en un caso de uso de los datos de movilidad de un conductor. Para ello se estimó que "*los patrones de movilidad de un conductor asociado a su estilo de vida permiten asignar de forma más eficaz su perfil de riesgo y por tanto permite optimizar el precio que una aseguradora ofrece a su cliente sin necesidad de recurrir a las variables clásicas de la frecuencia y tipo de conducción*". El resultado que se obtuvo, con una precisión del 92%, nos permite afirmar que una solución en donde se categorice y mida el perfil de riesgo de conductores de vehículos en base a nuestro modelo es una nueva aportación al mundo académico e industrial. Podemos confirmar que se presenta un modelo novedoso de análisis de riesgo de conductores basado en su geolocalización y ubicaciones visitadas. La contribución que refrenda esta hipótesis está basada en que aportamos una metodología nueva y más barata para que el sector asegurador pueda optimizar sus clasificadores de riesgos convencionales por el sistema descrito en el capítulo 5 que utiliza, por primera vez, elementos de geolocalización para categorizar el riesgo de un conductor.

Este sección es concluida con recordatorio y validación de la hipótesis general que describíamos en el capítulo 1 y que rezaba:

"*Si asociáramos un dispositivo para transformar un coche en un vehículo conectado, asegurando también la provisión de interfaces persuasivos, entonces reduciríamos los gastos asociados a tal vehículo e incrementaríamos su seguridad".*

Tal y como hemos desgranado en las 4 sub-hipótesis, arriba razonadas y validadas, embarcar tecnología de vehículo conectado a un automóvil ayuda a la transformación de éste en el sentido de dotar al vehículo de más capacidad (enviar mensajes) para que el conductor pueda recibir información y ésta se transforme en nuevos estímulos que permitan reducir el coste y la seguridad asociados a la movilidad.

6.3 Conclusiones

El avance de las Tecnologías de la Información y Comunicación ha causado toda una revolución en la vida de las personas a nivel global, permitiéndoles estar conectados a la web en tiempo real y acceder a gran cantidad de información que antes no estaba disponible. Gracias al avance de las TIC, las empresas han cambiado la forma convencional de llevar sus procesos de negocio, adaptándose a los cambios generados por las TIC, las cuales les han permitido optimizar sus procesos a partir del suministro de información detallada, oportuna y disponible, beneficiándose con una mejor toma de decisiones.

Gracias al mencionado avance de las TIC, los usuarios conductores de vehículos están mejor informados y conectados, mejorando su toma de decisiones de compra y consumo. Asimismo, estos usuarios confían en las TIC y recomiendan a otros usuarios el uso de estas TIC.

El trabajo de investigación de esta tesis, apoyado en tres artículos científicos publicados en revistas de alto impacto, concluye la tecnología afecta muy positivamente el ámbito de la movilidad desde 3 puntos de vista.

1) El primero, publicado en la revista "Sustainability" de MDPI, hace referencia al impacto de la tecnología embebida equipada con las técnicas de persuasión para así definir qué estrategias son las más adecuadas para el desarrollo de tecnología en el ámbito de la movilidad. El trabajo se centra en analizar cómo debe abordarse el desarrollo de tecnología que vaya a ser incorporada en un vehículo de manera que podamos influir lo máximo posible en un conductor. Para ello, este trabajo analizó los componentes tecnológicos que más influyen en el comportamiento de los usuarios. Todo esto se sistematizó a través de una encuesta que pretendía observar el comportamiento de una serie de conductores en base a jerarquizar las estrategias derivadas de los Principios Persuasivos.

   A través de la encuesta se han señalado las mejores estrategias para diseñar un artefacto de TI con principios de persuasión integrados para los conductores. Las conclusiones más relevantes de la encuesta nos llevaron a conocer qué principios de persuasión eran los más relevantes para el diseño de un artefacto o tecnología que influyera en los conductores. En este sentido, la recomendación para crear una nueva aplicación estará orientada a aumentar los mensajes personalizados para alertar al conductor. Nuestro enfoque ha permitido seleccionar los mejores principios persuasivos para la creación de tecnología en el ámbito del automóvil. Esas estrategias de persuasión nos deben servir de base a los modelos de reducción de costes.
2) Se realizó un segundo artículo científico, publicado en Applied Science de la editorial MDPI, que se basaba en analizar el impacto de la tecnología en un vehículo conectado respecto a

un vehículo no conectado en términos del gasto alrededor del vehículo. Es decir, se analizó si la tecnología embarcada en un vehículo permitía reducir el consumo alrededor de la movilidad. Para ello, primero se utilizó la metodología Delphi en donde pudimos concluir cuales eran los factores o determinantes más importantes que nos ayudarían a reducir los gastos de la movilidad del vehículo. Así, vimos que la tecnología juega, según los expertos, el papel más relevante. Para confirmar esa teoría, realizamos una encuesta en donde analizamos cuáles son los gastos del auto en vehículos conectados y no conectados. Los resultados de esa encuesta mostraron que los conductores con dispositivos tecnológicos integrados en sus automóviles gastan significativamente menos dinero en el mantenimiento del automóvil (es decir, gasolina, seguros, mantenimiento, servicio del automóvil, garaje, peajes, multas, impuestos y costos de reparación) que los conductores que no incluyen tecnología en sus autos.

Este análisis nos invitó a pensar que el mero hecho de disponer de tecnología con vehículos conectados posibilita que los conductores sean más conscientes del gasto que soportan alrededor de su vehículo y por tanto harán más acciones para reducir dichos gastos.

3) Además de la gestión del gasto alrededor del vehículo y su movilidad, la tecnología embarcada permite recoger y gestionar los datos de esos coches y sus desplazamientos. Las aseguradoras de automóviles se han interesado por este punto. Hasta ahora las aseguradoras basaban la cotización de un riesgo en la frecuencia del uso del coche, el tipo de coche y la siniestralidad histórica a través de una base de datos compartida por casi todo el sector que se llama SINCO. En nuestro tercer artículo científico de impacto, publicado en Energy Sources, Part A, de la editorial Taylor & Francis, hemos comparado el clasificador SINCO por uno desarrollado por los autores basado en los lugares que visita un conductor y la frecuencia con que lo realiza. Tal es así que podemos clasificar a los usuarios en conductores con vida más ordenada o vida más desordenada. El nivel de precisión de nuestro clasificador aportó una medida del 74%. Por tanto, hemos creado una nueva forma de evaluar el riesgo siniestral de un conductor en base a su geolocalización, pudiendo afirmar que existe una correlación entre los lugares que visita y la siniestralidad que un conductor tiene.

Esta tesis ha sido posible gracias a la colaboración entre el ámbito académico y una empresa y, por tanto, aquí hacemos mención a la transferencia de conocimiento entre la universidad y la empresa, mundos que deberían ir de la mano en un modelo de exploración y optimización de procesos. La tecnología y la metodología que se ha propuesto para el desarrollo de los sistemas tecnológicos embarcados en el auto son parte de la base del conocimiento que se ha adquirido y que ahora se comparte.

Además, el presente trabajo de investigación sirve de punto de partida para futuros trabajos de investigación basados en tecnologías de información, cuyo objetivo sea proponer soluciones enfocadas en mejorar la calidad de vida del usuario y en proteger el medio ambiente.

6.4 Trabajo futuro

A partir del presente estudio podemos afirmar que mediante la tecnología podemos obtener datos de los conductores y a partir del análisis del comportamiento de estos conductores podemos explotar este conocimiento en distintos escenarios. Esta caracterización de usuarios lo podemos extrapolar a otros ámbitos, siempre bajo el prisma de la movilidad y analizar el comportamiento de un ciudadano cuando visita establecimientos comerciales, por ejemplo, y eso se podría cruzar con los datos de los pagos que realiza con sus tarjetas bancarias.

Para mejorar esta capacidad de involucrar al usuario, hemos revisado una selección de las mejores estrategias de persuasión y estas mismas estrategias ya se ha comentado que se pueden aplicar en otros ámbitos del uso de la tecnología, por ejemplo, para influir en el consumo que hacemos las personas en el hogar (electrodomésticos, agua, luz, y resto de suministros).

Gracias a las metodologías aplicadas para conseguir, analizar y procesar los datos obtenidos, se puede afirmar que las (TIC) -en este caso, los dispositivos IoT - brindan a los conductores mayor confianza, dándoles información relevante acerca de los gastos en general de sus vehículos, con lo que pueden tomar mejores decisiones y mejorar su economía, haciendo que los conductores sean más conscientes sobre el dinero que gastan en sus vehículos.

La aplicación y el avance de las tecnologías aplicadas al ámbito de la movilidad permitirá una significativa evolución de las llamadas ciudades inteligentes ya que el comportamiento de la movilidad es una de las bases sobre las que las administraciones deben actuar para ofrecer ciudades más sostenibles, seguras y conectadas.

En la investigación de la tesis que ahora se presenta han surgido distintos focos de análisis y discusiones que por el contexto de los artículos presentados no ha sido posible abordar.

Tal y como se ha mencionado en la primera publicación que forma parte de esta tesis, se abordan las estrategias más adecuadas en términos de los principios de persuasión más efectivos que se deberían utilizar para conseguir la mayor atención, en este caso, de los conductores. Ese trabajo analizó el uso de los principios de persuasión como elemento fundamental con el objetivo de reducir los gastos en el ámbito de la movilidad. Además del foco sobre la que los autores han girado su investigación e hipótesis, podría haberse incorporado el prisma de una conducción más sostenible haciendo un uso más responsable del vehículo para desplazarse de un punto “A” a un punto “B” con el menor nivel de combustible posible, algo que redundaría también en una reducción de la contaminación. Estos mismos principios, asimismo, podrían ser de aplicación para la reducción de otros gastos corrientes que los ciudadanos gestionamos en el día a día. Así nos referimos a los gastos domésticos (electricidad, calefacción, agua) o al resto de gastos personales (gastos en comisiones bancarias, gastos en manutención, gastos de seguros, hipotecas y el resto de los gastos que conforman el día a día de cualquier ciudadano). Si cada uno de los gastos que realizamos en nuestra actividad ordinaria estuviera acompañado de una recomendación, guía o mensaje recordatorio a través, por ejemplo, de nuestro teléfono inteligente, podríamos observar también el comportamiento de la evolución de todos estos gastos, muy significativos, en la vida ordinaria. Así las cosas, se podrían presentar un análisis de los gastos de un conjunto de personas con un recomendador que facilitara información en tiempo real a través de Inteligencia artificial, utilizando como soporte un teléfono inteligente frente a usuarios que contaran con algún tipo de APP. El sistema de recomendación soportaría y enviaría recomendaciones algunos segundos antes de realizar el gasto.

Sería interesante publicar alguna investigación en este sentido para comprobar que efectivamente las personas podríamos ser más o menos permeables a determinadas recomendaciones dirigidas por un sistema inteligente que nos facilitara algún tipo de información. No obstante, es evidente que encontrar un balance entre inundar al usuario como demasiadas recomendaciones o con suficientes recomendaciones relevantes es todavía un aspecto complicado.

En esta misma línea, pero haciendo referencia al segundo artículo científico publicado en el capítulo 4, se cita literalmente que las personas que utilizan tecnología son más conscientes del dinero que se gasta en su auto alrededor de la movilidad de su vehículo. En este sentido no sólo ya podemos argumentar que la tecnología de la movilidad es importante, sino que, además, como indica el artículo, va a jugar un papel fundamental en el desarrollo de las ciudades transformando las ciudades en las que vivimos en ciudades inteligentes y conectadas, utilizando la tecnología como eje vertebral produciendo ahorros en la movilidad urbana. Este último punto es un reto que también nuestro alcance deja sin abordar, dado que requería de otro estudio más concreto y centrado en este ámbito. Por esta razón, se plantea como escenario de trabajos futuros en donde se analice no sólo el impacto que juegan las nuevas tecnologías en el diseño de las ciudades futuras, sino el impacto económico que la tecnología y los nuevos procesos juegan sobre el coste de los ciudadanos. Una hipótesis que debería tener respuesta en este estudio podría ser que la tecnología reduce los gastos de estructura de una administración y, por tanto, esa reducción en los gastos de gestión podría permitir una reducción de necesidad de recolectar impuestos y, por consiguiente, un ahorro para los ciudadanos. Esta hipótesis debería confirmarse con un estudio que aborde distintos gastos de los ciudadanos que suponen ingresos para las administraciones, tales como los aparcamientos, la utilización de espacio público para negocios privados o las tasas de basuras. Si la gestión se moderniza también podría ser que lo haga el sistema de gestión y por tanto se podría utilizar menos recursos.

En el tercer artículo que se ha presentado en esta tesis, queda por atender, tal y como el artículo reflexiona, qué variables adicionales se podrían haber tenido en cuenta en la categorización de conductores para su posterior clasificación (buenos o malos) en función de los datos de geolocalización. Así las cosas, el artículo apuntaba a nuevas dimensiones basadas en el razonamiento semántico para mejorar el modelado y por tanto la caracterización de los conductores. Además, se debería trabajar en la inclusión de nuevas dimensiones tales como si los datos que se recogen los diurnos o nocturnos, ya que es un factor clave para entender determinados comportamientos (el lector podría reconocer que no es lo mismo que un vehículo estacione en una zona de restaurantes a las 2pm vs a las 2am) del conductor. En esta misma línea, no se han incluido en el clasificador del análisis de riesgo de los usuarios variables de tiempos de no uso del auto, tales como los períodos de vacaciones u otras circunstancias ahora más habituales dada la limitación del uso de la movilidad por el efecto, por ejemplo, del teletrabajo. Sepa el lector que si un asegurado, por sus nuevas condiciones de vida (imaginemos que se convierte en un trabajador virtual) y ese trabajador ya no necesita el vehículo y por tanto lo vende, para el conjunto del sector seguros, si este usuario, pasados 365 días vuelve a solicitar un seguro por un nuevo vehículo, este se realizará como si el conductor fuera nuevo y por tanto no tuviera experiencia previa histórica. Este es un punto muy relevante ya que esta distorsión que hoy ofrece el clasificador habitual en las compañías aseguradoras no lo tiene en cuenta.

Estas limitaciones al alcance del trabajo aquí presentadas son nuevas oportunidades de investigación que redundarían en un análisis más profundo del aquí presentado y, por tanto, una investigación adicional para continuar con el análisis del impacto de la tecnología en el ámbito de la presión del gasto en los ciudadanos y la racionalidad de los desembolsos que éstos realizan en sus actividades ordinarias.

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