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TRACKBEST-3S

Herramienta para la Gestión Segura, Sostenible e Inteligente de Rutas de Autobús

Tool for Management of Safe, Sustainable and Smart Bus Routes

ENTREGABLE 5.5
PLAN DE DIFUSIÓN DE LA INNOVACIÓN

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1. INTRODUCCIÓN

El transporte de viajeros en autobús resulta clave para asegurar la equidad territorial y social de los países más desarrollados y, mucho más, de los países en vías de desarrollo. En los viajes de larga distancia, el autobús tiene en España una cuota de mercado superior al ferrocarril, aportando servicios de capilaridad en todo el territorio. Por otra parte, en la movilidad urbana y metropolitana, el autobús es el modo de transporte público dominante, salvo en las grandes metrópolis de Madrid y Barcelona, donde también lo es en sus respectivas coronas metropolitanas. Estos beneficios sociales, junto con sus menores costes y flexibilidad de recorridos, hacen de los servicios de autobús la red base necesaria para asegurar la movilidad de largo y corto recorrido. Sin embargo, son también causa de externalidades ambientales como ruido, contaminación y Gases de Efecto Invernadero (GEI); y sociales como accidentes, diferencias de accesibilidad.

La mejora de la calidad de los vehículos y las tecnologías de información y comunicación están abriendo nuevos campos para lograr mayores beneficios sociales, reducir las externalidades y aumentar su competitividad económica y empresarial. Sólo las empresas que apuestan por la innovación e integración de sistemas pueden mejorar su posición competitiva y la calidad del servicio orientado al viajero.

La mejora de los servicios de autobús tiene un gran potencial de cara a conseguir un sistema de transporte sostenible y eficiente, donde este modo juegue un papel vertebrador en el contexto de un sistema de transporte multimodal, tanto en la movilidad de larga distancia como en la movilidad urbana y metropolitana. Para ello, estos servicios tienen que asegurar la calidad de sus prestaciones para competir con el automóvil y contribuir a la reducción de emisiones y consumos energéticos.

Entre los principales desafíos a los que se enfrenta el autobús es que está sujeto a las condiciones del tráfico y su velocidad comercial es más dependiente de las condiciones del entorno que para otros modos de transporte público (Van de Velde, 2009). Además, el autobús suele percibirse como menos fiable, particularmente con relación a la información de ruta, características de especial relevancia para la calidad de los servicios de transporte (Hensher et al., 2003). Por último, aunque la energía consumida por viajero en los autobuses es cinco veces inferior a las de los vehículos privados (Ministerio de Fomento, 2006), se podrían lograr mayores ahorros energéticos con una conducción más eficiente. Esto supondría una reducción de costes y una mejora medioambiental, especialmente dado que el 95,4% de la flota de autobuses española utiliza combustibles fósiles (DGT, 2018a). Como se puede evidenciar, las principales mejoras a implementar en los servicios de autobús se refieren a la eficiencia, la seguridad, la fiabilidad y la información (EC, 2011).

2. MOTIVACIÓN DEL PROYECTO

El presente proyecto tiene como principal motivación desarrollar una herramienta de gestión de flotas de autobuses, TrackBest-3S, que permita mejorar la eficiencia y la calidad de los servicios de autobús. El principal avance con respecto a la situación actual de la técnica es que TrackBest-3S ahonda en la eficiencia de los servicios de autobús combinando la seguridad, las emisiones de GEI y gases contaminantes y la fiabilidad del servicio, posibilitando así una triple optimización de la operación (Safe, Sustainable and Smart - 3S).

Siendo ALSA el principal operador de autobús de España, se encuentra altamente interesado en implementar soluciones tecnológicas de primer nivel para la gestión de sus flotas, de manera que estas reviertan en la mejora continua del servicio que provee a los pasajeros.

El proyecto también cuenta con la participación del Centro de Investigación del Transporte de la Universidad Politécnica de Madrid (TRANSyT-UPM), centro de I+D+i de reconocido prestigio a nivel nacional e internacional en el estudio de la movilidad y sus efectos. La confluencia de estos dos socios proporciona sinergias con mucho potencial en la realización de proyectos de alto nivel de innovación.

ALSA ha integrado sistemas de gestión en su vehículos (GPS), los cuales permiten la visualización remota de rutas y la creación de una base de datos histórica de cada ruta con todas las variables de explotación (demanda) y operación (consumos, velocidades, aceleraciones, emisiones, etc.). Estos datos, junto con datos abiertos en tiempo real sobre tráfico y congestión y de puntos de medida de gases contaminantes y de GEI, servirán como base para la creación de la herramienta.

El estudio de la herramienta TrackBest-3S se llevará a cabo en tres casos de estudio: dos zonas urbanas (Oviedo-España y Tánger-Marruecos) y un corredor de larga distancia (Madrid-Burgos-Bilbao).

3. OBJETIVOS DEL PROYECTO

La meta integral de TrackBest-3S es mejorar la eficiencia y la calidad de los servicios de autobús. Este objetivo principal tendrá beneficios a tres niveles: operador, pasajero y sociedad. Para conseguirlo, el proyecto tiene tres objetivos principales que se alcanzarán a través de una serie de objetivos específicos.

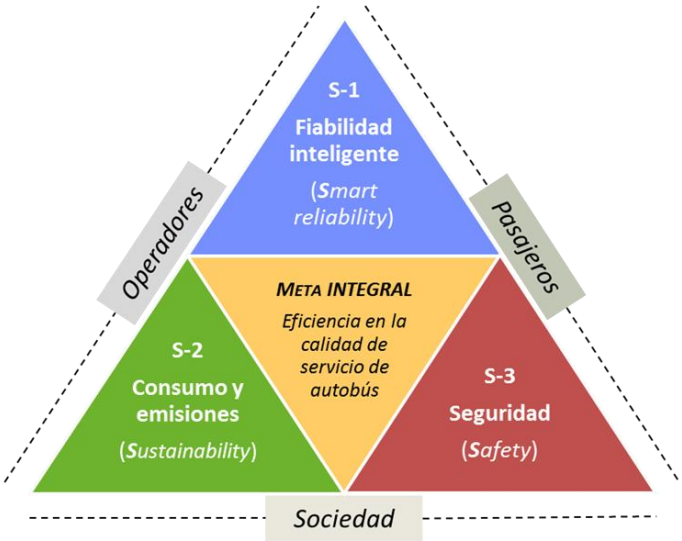

Figura 1. Marco para la integración de fiabilidad, emisiones y seguridad en TrackBest-3S
Fuente: Elaboración propia

3.1. Objetivo 1 - Mejorar la fiabilidad del servicio

El primer objetivo de esta herramienta consiste en mejorar la operación del servicio, tomando como parámetros la puntualidad y regularidad del servicio. Este es uno de los aspectos clave para los operadores de transporte, pero también para los viajeros. La Comisión Europea señala en su Libro Blanco (2011) la necesidad de unos servicios de transporte fiables, entre otras cosas, debido al envejecimiento de la población y a la necesidad de fomentar el transporte público. Dicha regularidad depende en gran medida del tipo de servicio ofertado (urbano o larga distancia), ya que las características de la infraestructura y del flujo del tráfico difieren en aspectos muy diversos.

A nivel de larga distancia, los dos atributos más valorados por los usuarios en el contexto español son la puntualidad de salida y de llegada (Ministerio de Fomento, 2015c), aspectos íntimamente ligados con la fiabilidad del servicio. En cambio, los principales problemas de operación de los servicios de autobús en entornos urbanos son el agrupamiento de autobuses (bunching), y la congestión. El primero se debe a que los retrasos del primer autobús en línea hacen que haya más pasajeros en las paradas y se aumente el retraso. En el siguiente autobús embarcan menos pasajeros, por lo que reduce su tiempo parado mientras que el primero circula cada vez con mayor retraso, lo que ocasiona que el segundo autobús alcance al primero. La mayoría de las estrategias para evitar el agrupamiento se basan en la distribución del intervalo de paso real y su relación con el intervalo planeado (Cats, 2014). A este problema se suma la congestión de las vías urbanas, produciendo efectos sinérgicos, negativos y aleatorios.

Este objetivo se articulará a través de los siguientes objetivos específicos:

- OE 1.1. Reducir tiempos de recorrido de los servicios de autobús.
- OE 1.2. Incrementar la puntualidad en origen y destino en servicios de larga distancia.
- OE 1.3. Garantizar frecuencias de paso en servicios urbanos.
- OE 1.4. Aumentar el número de viajeros.
- OE 1.5. Mejorar la satisfacción con el servicio.

TrackBest-3S evaluará la fiabilidad del servicio utilizando el tiempo de recorrido entre tramos o franjas horarias disponible gracias al sistema de geolocalización de la flota. Estos datos permitirán identificar variaciones recurrentes en la fiabilidad en determinadas líneas las cuales serán analizadas para identificar si se deben a las condiciones de operación, las condiciones climatológicas o el tráfico. Esta mejora de la fiabilidad del servicio permitirá que la información en tiempo real proporcionada a los usuarios aumente su satisfacción (Gooze, Watkins and Borning, 2013; Brakewood, Barbeau and Watkins, 2014).

3.2. Objetivo 2 - Mejorar la sostenibilidad ambiental asociada al autobús

El segundo objetivo de TrackBest-3S es reducir la energía consumida y las emisiones emitidas. El consumo depende principalmente de las características del vehículo, del trazado y de la velocidad (Hu et al., 2013; Shek y Chan, 2008). Este último factor está muy relacionado con el estilo de conducción, por ello, en la última década los operadores de autobús han formado a los conductores en técnicas de conducción eficiente, logrando reducir hasta un 10% el consumo de combustible (Rutty et al., 2013; Zarkadoula, 2007).

Además, la mayor parte de las flotas de autobuses están compuestas por vehículos de combustión. Por ello, el consumo energético de los autobuses está ligado a la emisión de GEI y la emisión de gases contaminantes (EC Delft, INFRAS, and Fraunhofer ISI, 2011). La reducción de emisiones contribuirá a mejorar la calidad del aire, un objetivo especialmente importante en las ciudades.

La decisión de cambiar el recorrido de las rutas no depende habitualmente de los operadores de autobús, corresponde al Ministerio de Fomento en el caso de larga distancia y a las Autoridades de Transporte Público en entornos urbanos y metropolitanos. Por este motivo, TrackBest-3S no puede aplicar en el concepto de "eco-rutas" para mejorar la sostenibilidad ambiental en las rutas de autobús que opera. Sin embargo, como el consumo y las emisiones dependen tanto de las características de la flota y del estilo de conducción, TrackBest-3S buscar reforzar las formaciones periódicas de conducción eficiente realizadas por ALSA a sus conductores para reducir el consumo y las emisiones. Por otro lado, TrackBest-3S evaluaría de forma regular las variaciones en los consumos y las emisiones derivados de la constante actualización de la flota por tecnologías menos contaminantes.

Este segundo objetivo se puede concretar en los siguientes objetivos específicos:

- OE 2.1. Reducir el consumo de combustible.
- OE 2.2. Disminuir las emisiones de GEI y de gases contaminantes.
- OE 2.3. Promover la adopción de patrones de conducción eficiente.

3.3. Objetivo 3 - Descender la accidentalidad

El último objetivo de la herramienta será mejorar la seguridad para reducir los accidentes y las situaciones de peligro en las rutas. La necesidad de alcanzar este objetivo depende de la situación socioeconómica del país. Por un lado, en países desarrollados, las tasas de fallecidos por accidentes de tráfico, y especialmente en accidentes de autobús, son notablemente bajas (9,3 fallecidos en accidentes de tráfico por cada 100.000 habitantes en Europa). Mientras que en regiones con menor desarrollo la tasa de fallecidos en accidentes de tráfico se llega a duplicar (20,7 en el Sudeste asiático) o a triplicar (26,6 en África) (WHO, 2018).

En Marruecos, sede de uno de los casos de estudio, los últimos datos disponibles muestran que un 2% de los fallecidos en accidentes de tráfico fueron en autobús. En términos absolutos, 77 personas perdieron la vida en accidentes de autobús. En España, el porcentaje de accidentes de tráfico con víctimas con autobuses implicados es marginal (2,1%). En el año 2017, hubo 2.202 accidentes en los que estuvieron implicados autobuses. En estos accidentes hubo un total de 47 heridos hospitalizados, de los cuales fallecieron un total de tres personas (DGT, 2017). Aunque el porcentaje de accidentes de tráfico con autobuses implicados es marginal es especialmente relevante reducir estas cifras, ya que los accidentes que se dan en transporte colectivo tienen un impacto social más elevado que los que se dan en transporte privado (Slovic et al., 1984). Por ello, no solo es importante que el autobús sea objetivamente más seguro que otros modos, sino que también la sociedad perciba el transporte en autobús como un modo extremadamente seguro.

Este objetivo se divide en cuatro objetivos específicos:

- OE 3.1. Reducir el número de accidentes de tráfico.
- OE 3.2. Reducir el número de víctimas.
- OE 3.3. Garantizar el cumplimiento de los límites de velocidad.
- OE 3.4. Mejorar la seguridad percibida a bordo.

4. PAQUETES DE TRABAJO

4.1. PT 0 - Coordinación y gestión del proyecto

El paquete de trabajo PT 0 tiene como objetivo facilitar la adecuada gestión del proyecto. Para ello debe asegurarse una correcta coordinación de los flujos de trabajo, de datos y de recursos, tanto materiales como humanos, para garantizar una eficiente ejecución del proyecto desde todos los puntos de vista: técnico, administrativo-financiero y cronológico.

La gestión del proyecto facilita el aseguramiento, organización y coordinación de todos los recursos necesarios para garantizar la correcta ejecución del proyecto y la satisfacción de todos los grupos de interés implicados en el mismo, estableciendo adecuados mecanismos de control sobre el proyecto con el fin de garantizar la coordinación de los socios implicados en el proyecto, la estrategia de comunicación y flujo de la información, y la metodología de ejecución del proyecto.

4.2. PT 1 - Análisis técnico y de mercado

El paquete de trabajo PT 1 busca conocer en detalle la situación existente en la gestión inteligente y conectada de los servicios de autobús, así como la situación en los tres objetivos del proyecto: fiabilidad inteligente, sostenibilidad ambiental y seguridad vial. Para ello, se realizará un proceso sistemático de análisis de la situación en las tres áreas fundamentales de la innovación: estrategias políticas, avances científicos e innovación en el mercado.

El análisis de programas, planes y estrategias políticas en estos ámbitos está orientado a alinear correctamente TrackBest-3S dentro de las necesidades de la sociedad. Por su parte, la revisión de los avances científicos permite conocer en detalle qué factores deben tenerse en cuenta para el desarrollo y evaluación de la herramienta. Finalmente, el análisis de la innovación en el mercado permitirá detectar experiencias similares en el desarrollo y la operación, así como encontrar aspectos que puedan constituir una ventaja competitiva.

4.3. PT 2 - Marco tecnológico y operativo

El paquete de trabajo PT 2 comprende los trabajos previos para la preparación de un marco tecnológico y operativo en el que se desarrollará la herramienta TrackBest-3S, fundamentalmente consistentes en tres partes: la caracterización de los casos de estudio donde se testará la herramienta, la captura y estructuración de los datos de esos casos de estudio y la integración con las herramientas de visualización que posee ALSA. La preparación inicial del marco de desarrollo del proyecto permitirá minimizar los problemas de carácter tecnológico durante el desarrollo y evaluación de TrackBest-3S.

4.4. PT 3 - Desarrollo de TrackBest-3S

El paquete de trabajo PT 3 consiste en el desarrollo de la herramienta, dando como resultado el producto TrackBest-3S. La herramienta está dividida en tres módulos, entendidos como subprogramas dentro de TrackBest-3S, que están alineados con los tres objetivos del proyecto: un primer módulo de fiabilidad, otro de consumo y emisiones y el último de seguridad vial.

4.5. PT 4 - Aplicación y evaluación de TrackBest-3S

TrackBest-3S se aplicará a todos los casos de estudio (T 2.2) para verificar su utilidad en las distintas situaciones (larga distancia vs. movilidad urbana, con los distintos condicionantes de conducción y disponibilidad de datos, movilidad urbana en país desarrollado vs. país en vías de desarrollo). Este paquete contempla una evaluación cuantitativa y una evaluación cualitativa.

4.6. PT 5 - Impactos y transferencia de resultados

Los objetivos de este paquete de trabajo son, por un lado, conocer los impactos producidos por TrackBest-3S y, por el otro, transferir los resultados del proyecto al mercado y a la sociedad. La medición de los impactos económicos, sociales y ambientales permitirá cuantificar los beneficios que aporta TrackBest-3S a operadores, pasajeros y a la sociedad.

También se realizará un plan de transferencia de los resultados del proyecto al conjunto de la sociedad, sirviendo como base de propuestas de I+D+i para las convocatorias europeas pertinentes.

5. DIFUSIÓN DE LA INNOVACIÓN

A lo largo de todo el proceso de trabajo e investigación, TRANSyT se encargará de la difusión de conocimiento de interés académico a través de publicaciones específicas del sector y círculos académicos. Asimismo, los resultados del proyecto se presentarán en congresos nacionales e internacionales de gran prestigio.

5.1. Publicaciones de carácter científico

5.1.1. Cortez, A., Monzón, A., & Al Akioui, A. (2021). Cross-case analysis of bus operation in different context: Oviedo (Spain) and Tangier (Morocco). *R-Evolucionando el Transporte*. Universidad de Burgos.

One of the main problems in urban areas is the steady growth in car ownership and traffic levels. Therefore, the main challenge to reach sustainable and liveable cities is focused on a shift of the demand for mobility from cars to collective means of transport. For this purpose, buses are a key element of the public transport system. This paper presents a cross-case analysis, from a diagnostic through big data management of the urban bus operation in Oviedo (Spain) and Tangier (Morocco). For this aim, several performance indicators (KPIs) were estimated for both networks and services. In the evaluation of the service the KPIs were grouped in five categories considering the consumption of resources (inputs) and the results or production obtained (outputs). Once the KPIs were estimated, they were compared to minimum requirements needed to satisfy demand depending on the cities characteristics (population, cover area, alternative transport systems). Finally, a qualitative comparison of the overall performance of the two networks was done. Results showed that even though at first sight, the service characteristics might seem different:

Tangier´s network is made up of 44 lines, with a length of 795 km and a fleet of 192 buses. While Oviedo´s network has 16 lines with an extension of 205.9 km and a fleet of 67 buses there are several common indicators like the monthly average of users in urban lines that rounds 125,000 passengers, a capture ratio of 40 persons per bus, and a similar bus availability every 1000 inhabitants (0.22 and 0.30). However, it was possible to observe some gaps in the system functioning, mainly in Tangier´s network which overall performance is worse than Oviedo´s in most of the analysed aspects.

5.1.2. Al Suleiman, S., Cortez, A., & Monzón, A. (2023). Evaluation of urban bus service quality in a medium-sized city: Oviedo. *Innovación en Movimiento*. Universidad de La Laguna.

The negative effects of mobility, such as traffic congestion, greenhouse gas (GHG) emissions, pollutant emissions, and traffic accidents, are growing as urban travel patterns get more complicated. Promoting the use of public transportation (PT) has become one of the main policy objectives in most countries. To foster a change from private vehicle to PT, it is necessary first to identify the weaknesses and strengths of the PT system through the assessment of users' perception of the services. This study focuses on the bus services of Oviedo (Spain), which can be considered a representative sample of a medium-sized European city. The analysis is based on a survey conducted on passengers to assess their satisfaction with the service and the factors affecting their valuations. A two-step procedure that combines a classification model (CART model) and Importance Performance Analysis (IPA) was used. Results showed that the attributes related to comfort, information, frequency, and schedule on working days are classified as -strong performers-. On the other hand, special attention should be paid to: 'Service start/end time on holidays' and 'Frequency and schedule on holidays and weekends', as they were identified as important attributes with weak performance. The methodology applied allowed us to identify the most important attributes for urban bus users and can serve bus operators in other European medium-sized cities to have a clear overview of where to allocate resources. Results showed that it is necessary to pay extra attention to the service during weekends and holidays.

5.1.3. Cortez, A., & Monzón, A. (2023). Assessing urban users' satisfaction in Tangier, a developing medium-sized city. *Innovación en Movimiento*. Universidad de La Laguna.

The steady rise in car ownership and the resulting negative externalities are some of the biggest problems that cities must deal with. As a result, it is necessary to speed up the shift to sustainable mobility by fostering the use of collective modes of transport. Among the different alternatives, buses are considered the most popular and accessible mode of transport being a vital part of every public transport system. Mobility differs significantly between developing and developed countries, in most developing countries, the private car is the dominant mode due to the low quality of public transport (PT). To achieve the much-needed shift towards sustainable modes, it is essential to assess users´ perceptions of the service. This study focuses on urban bus services of Tangier (Morocco) which is a typical Arab medium-sized city. Moreover, and as in most developing countries, the public transport of this city relays on buses which are the only mode available. Passengers´ satisfaction was assessed through a survey that besides identifying their socioeconomic and trip characteristics, was mainly focused on evaluating their satisfaction with ten service attributes. An Exploratory Factor Analysis (EFA) of the survey data was used to identify key latent factors related to users´ satisfaction that were not directly measured on the questionnaire. In this case, 3 factors were found to be the most important ones: supply, comfort & purchasing, and service hours. Finally, the overall satisfaction (OS) with the service was then explained based on the factors identified using an ordinal logistic regression model that ranks the importance of the attributes identified in the EFA. It was observed that passenger´s satisfaction with service supply and comfort & purchasing is most influential their overall satisfaction.

5.1.4. Rahnama, S., Cortez, A., & Monzón, A. (2023). Is bus passengers' satisfaction influenced by company's application and website features in long-distance bus service*? Innovación en Movimiento*. Universidad de La Laguna.

The bus is the most used and popular mean of public transport in the world. For this, it is essential to measure customer satisfaction to increase the quality level of service. Most studies in the transportation sector have looked at user satisfaction with a company's information channels (website/Mobile app) focused on purchasing tickets. Few studies, however, have examined how the different attributes of the information channels affect users' overall satisfaction (OS) with the service. The intercity line between Madrid and Bilbao was chosen as the case study. Passengers´ satisfaction was assessed through a survey. This data was collected using a hybrid methodology at the Avenida-America interchange in Madrid, which is the origin of the journey between these cities. An ordinal probit regression was used to model how users´ value of different affirmations about information channels´ features affects their OS. The results showed that men prefer to use the website while women are more likely to use the mobile app. In addition, mobile app users are commonly between 18 and 25 years old, while website users tend to be between 36 and 60 years old. Results also showed that the data reliability of both, the mobile app and the web influence the likelihood of OS. In addition, "define preferences of the ticket price for my journey" influences web users' OS. Although web and app users have different profiles, both focused on the same aspects. The insights from this work can help operators to identify the most important attributes of their information channels to increase passenger satisfaction.

5.1.5. Al Suleiman, S., Cortez, A., & Monzón, A. (2023). Evaluation of urban bus service quality in a medium-sized city: Oviedo. *Transportation Research Procedia*.

The negative effects of mobility, such as traffic congestion, greenhouse gas (GHG) emissions, pollutant emissions, and traffic accidents, are growing as urban travel patterns get more complicated. Promoting the use of public transportation (PT) has become one of the main policy objectives in most countries. To foster a change from private vehicle to PT, it is necessary first to identify the weaknesses and strengths of the PT system through the assessment of users' perception of the services. This study focuses on the bus services of Oviedo (Spain), which can be considered a representative sample of a medium-sized European city. The analysis is based on a survey conducted on passengers to assess their satisfaction with the service and the factors affecting their valuations. A two-step procedure that combines a classification model (CART model) and Importance Performance Analysis (IPA) was used. Results showed that the attributes related to comfort, information, frequency, and schedule on working days are classified as -strong performers-. On the other hand, special attention should be paid to: 'Service start/end time on holidays' and 'Frequency and schedule on holidays and weekends', as they were identified as important attributes with weak performance. The methodology applied allowed us to identify the most important attributes for urban bus users and can serve bus operators in other European medium-sized cities to have a clear overview of where to allocate resources. Results showed that it is necessary to pay extra attention to the service during weekends and holidays.

5.1.6. Rahnama, S., Cortez, A., & Monzón, A. (2023). Is bus passengers' satisfaction influenced by company's application and website features in long-distance bus service*? Transportation Research Procedia*.

The bus is the most used and popular mean of public transport in the world. For this, it is essential to measure customer satisfaction to increase the quality level of service. Most studies in the transportation sector have looked at user satisfaction with a company\xB4s information channels (website/mobile app) focused on purchasing tickets. Few studies, however, have examined how the different attributes of the information channels affect users' overall satisfaction (OS) with the service. The intercity line between Madrid and Bilbao was chosen as the case study. Passengers\xB4 satisfaction was assessed through a survey. This data was collected using a hybrid methodology at the Avenida-America interchange in Madrid, which is the origin of the journey between these cities. An ordinal probit regression was used to model how users\xB4 value of different affirmations about information channels\xB4 features affects their OS. The results showed that men prefer to use the website while women are more likely to use the mobile app. In addition, mobile app users are commonly between 18 and 25 years old, while website users tend to be between 36 and 60 years old. Results also showed that the data reliability of both, the mobile app, and the web influence the likelihood of OS. In addition, "define preferences of the ticket price for my journey" influences web users' OS. Although web and app users have different profiles, both focused on the same aspects. The insights from this work can help operators to identify the most important attributes of their information channels to increase passenger satisfaction.

5.1.7. Al Suleiman, S., Cortez, A., Monzon, A., & Lara, A. (2023). How to improve public transport usage in a medium-sized city: Key factors for a successful bus system. *European Transport Research Review*.

In recent years, the promotion and use of public transport (PT) has become key to overcoming the negative impacts of mobility, such as traffic congestion, high pollution (GHG), and traffic accidents. Improving users' satisfaction and increasing the attractiveness of buses play an essential role in increasing PT patronage. Whilst most of the literature concentrates on large and complex bus systems, less attention has been paid to European medium-sized cities, the region's most common urban configuration, where public transport mainly depends on bus services. To this end, a survey campaign was conducted on passengers of urban buses in Oviedo, Spain, a representative medium-sized city. An Exploratory Factor Analysis (EFA) was used to identify key user satisfaction factors. In this case, three factors were the most important: comfort and information, service performance, and integration. That was complemented by the overall satisfaction (OS) with services, which was used for ranking the importance of the factors using an ordinal logistic regression model; comfort and information appear as the most important. These findings can serve bus operators to identify service-related attributes that need more attention or investment to increase users' satisfaction and to make the service attractive to potential users.

5.1.8. Rahnama, S., Cortez, A., & Monzon, A. (2023). An expert tool for investigating key explanatory factors for safer bus operation. *Transportation Research Procedia*.

Buses are among the most accessible and frequently used means of transport. Due to its importance, road safety analysis is frequently done to reduce accidents. This paper studied the relation between weather conditions and causes of accidents to improve road safety. The focus is on the long-distance services between Madrid and Bilbao (Spain). Latent Class Clustering (LCC) and Hierarchical Ordered were used to identify the relation between those factors. The main result shows a downward trend in the number of accidents since 2019 and manoeuvres from all causes of accidents receive the highest percentages. LCC shows that "manoeuvres and Car invading lane in opposite direction" in a "clear and cloudy weather" has the highest probability of happening (63%). The Hierarchical Ordered methodology shows that rainy weather has a highly significant relationship with all the causes of accidents.

5.2. Congresos, conferencias y jornadas

5.2.1. Cortez, A., Monzón, A., & Al Akioui, A. (2021). *Cross-case analysis of bus operation in different context: Oviedo (Spain) and Tangier (Morocco)*. XIV Congreso de Ingeniería del Transporte - CIT 2021. 6-8 de julio de 2021. Burgos, España.

One of the main problems in urban areas is the steady growth in car ownership and traffic levels. Therefore, the main challenge to reach sustainable and liveable cities is focused on a shift of the demand for mobility from cars to collective means of transport. For this purpose, buses are a key element of the public transport system. This paper presents a cross-case analysis, from a diagnostic through big data management of the urban bus operation in Oviedo (Spain) and Tangier (Morocco). For this aim, several performance indicators (KPIs) were estimated for both networks and services. In the evaluation of the service the KPIs were grouped in five categories considering the consumption of resources (inputs) and the results or production obtained (outputs). Once the KPIs were estimated, they were compared to minimum requirements needed to satisfy demand depending on the cities characteristics (population, cover area, alternative transport systems). Finally, a qualitative comparison of the overall performance of the two networks was done. Results showed that even though at first sight, the service characteristics might seem different:

Tangier´s network is made up of 44 lines, with a length of 795 km and a fleet of 192 buses. While Oviedo´s network has 16 lines with an extension of 205.9 km and a fleet of 67 buses there are several common indicators like the monthly average of users in urban lines that rounds 125,000 passengers, a capture ratio of 40 persons per bus, and a similar bus availability every 1000 inhabitants (0.22 and 0.30). However, it was possible to observe some gaps in the system functioning, mainly in Tangier´s network which overall performance is worse than Oviedo´s in most of the analysed aspects.

5.2.2. Al Suleiman, S., Cortez, A. & Monzon, A. (2022). *Towards safer, sustainable, and smart public transport. Oviedo Case Study*. IV Campus Científico del Foro de Ingeniería del Transporte - FIT 2022. 25-26 de mayo de 2022. Cercedilla, España.

Urban growth is a worldwide phenomenon which has many side effects. In 2018, 55.3% of the world's population lived in urban areas and this percentage is expected to rise to 60.4% by 2030. Consequently, impacts related to mobility like traffic congestion, GHG and pollutant emissions, traffic accidents are expected to grow.

This research focuses on the city of Oviedo, with 220,000 inhabitants which can be considered a representative sample of medium-sized cities in Spain. Moreover, its public transportation system is mostly based on TUA bus services which is a private company of ALSA Group. The bus network of Oviedo has 15 daytime lines and one night-time line, with a fleet of 67 buses to cover the service. Total ridership in 2019 was some 12 million passengers.

After reviewing previous studies that identified the key factors explaining the overall users´ satisfaction, it was found that little research was done on the satisfaction of urban buses after COVID-19 lockdown and operation with restrictions. This supports the need for this work to determine these factors.

The research followed the following steps to achieve the objective of characterizing traveler's satisfaction during pandemic restrictions.

Step 1 – Gathering Data Survey

To then end a survey campaign was conducted between November 15th and 19th of 2021. This survey was made up of 21 questions, structured in three sections: socioeconomic data, characteristics of the trip, and satisfaction with the service. In the campaign, passengers were interviewed in person on board and at some specific stops. The total number of answers was 982 responses of which 970 were valid. From the 21 questions, this research focuses on evaluating the 13 items related to service quality, measured through a Likert scale of 1-5.

I1 Info on schedules and frequencies at stops I2 Information inside the bus I7 Travel comfort (number of travelers) I8 Smooth driving (curving, braking) I9 Frequency and times on working days	I10 Frequency and schedule on holidays and weekends I11Compliance with schedules and frequencies I12 Service start/end time on business days I13 Service start/end time on holidays.
I4 Extent of the bus network	I3 Connection with other modes (rail, interurban bus) and between lines I5 Ticket price I6 Ease of purchasing passes/cards

Step 2 –Analysis and Modelling

First, a descriptive analysis of the answers to these 13 items related to perceived quality was done. Then, a Factor Analysis (FA) was performed to evaluate the relationship between the variables related to service satisfaction, with the aim of grouping these attributes in order to identify latent variables. Finally, Regression Models were used to understand causal relationships between these latent variables and Overall Satisfaction OS.

The results of the FA identified clearly 3 different latent variables:

- F1: Comfort includes 5 items (I1, I2, I7, I8, I9).
- F2: Service Performance includes 4 items:(I10, I11, I12, I13).
- F3: Integration grouped 3 (I6, I5, I3)

I4 was discarded because it was not included in any of the previous factors, and it had a low loading coefficient (smaller than 0.50),

An Ordinal Logistic Regression (Ologit) model was performed to calculate the importance of the 3 identified factors to explain overall satisfaction. The results are the following.

Factors	Coeff (β)
F1. COMFORT	1.346905
F2. SERVICE	0.487227
F3. INTEGRATION	0.515476

The *Comfort* factor (1.35) was the most important, while the other two factors, *Service Performance* (0.48) and *Integration* (0.51), showed almost the same importance.

There will be a similar future study for the city of Tangier in Morocco, which is also a medium urban city, with a similar methodology. Then a comparison between the two cities will be performed to analyse which socioeconomic and cultural factors could explain their differences.

5.2.3. Rahnama, S., Monzón, A. & Cortez, A. (2022). *Holistic Evaluation of Long-Distance Bus Services Performance*. IV Campus Científico del Foro de Ingeniería del Transporte - FIT 2022. 25-26 de mayo de 2022. Cercedilla, España.

Bus passenger transport is the key to a sustainable mobility, both for urban and long-distance services. Moreover, Spain has a higher bus market share than most European countries which supports the constant need to improve the service to make it more attractive to users.

TrackBest-3S is a project related to improve long-distance (Madrid-Bilbao) and urban (Oviedo and Tangier-Morocco) bus services by developing a management tool. This tool aims to integrate all this information in an expert system which will allow a triple optimization of the operation (Safe, Sustainable and Smart-3S), achieving the following 4 project objectives:

1. Reduce the accident rate.
2. Improve the environmental sustainability.
3. Improve service reliability.
4. Increase passenger satisfaction.

A set of KPIs was defined to evaluate the performance of the service in the three different modules (safe, sustainable, smart). By investigating in pervious researches and works in this area the KIPs are choose due to the highest compliance to our project. To estimate each KPI, data from the operator ALSA together with other sources data were used. In the case of Madrid-Bilbao, data from 2019, 2020 and 2021 was considered. Since the service has different lines, the main line with normal type of buses (line 3235) which is the most used and frequent was analyzed. Moreover, to evaluate passenger satisfaction TRANSyT conducted a survey campaign in two different periods at Avenida America Interchange of Madrid.

Objective 1- Safe

To evaluate the safety of the service the Vehicle Accident Rate (VAR) was estimated.

$$VAR = \frac{Number\ of\ accidents * 10^6}{Total\ km}$$

Table 1 show VAR in research case study in three years. The highest and the lowest VAR registered in 2019 and 2020 respectively. The second can be attributed to the COVID-19 lockdown.

Table 1. Vehicle Accident Rate in 2019-2020-2021

Year	Number of accidents	Total km	Vehicle Accident Rate (VAR)
2019	65	3,958,217	16.42
2020 (Pandemic)	19	1,742,009	10.91
2021	30	2,374,930	12.63

Objective 2- Sustainability

To reach reducing greenhouse gas (GHG) and pollutant gas emissions, the estimation of PM2.5 and CO_2 from the fleet is essential. For this, SUMI a European emission standards tool was used. Table 2 shows the amount of PM2.5 and GHG in three years related to the all of trips between Madrid to Bilbao. As expected, the lowest measures were registered in 2020 both measures due to the lockdown.

Table 2. Emission and consumption in 2019-2020

Year	Total km	g(PM2.5)/l	g(CO_2)/l	Average Consumption (l/100km)
2019	3,958,217	0.108	1122.7	30.10
2020 (Pandemic)	1,742,009	0.107	1106.0	29.33

For second sub-objective of sustainability (reduce consumption), the spreadsheet-based Optimizing Public Transport Investment Costs (OPTIC) Model was chosen as a standard for comparison. Since the buses in this study are diesel vehicles that are also more than five years old, the model with a consumption of 49.5 l/100km was selected.

Table 2 shows the average of consumption in 2019 and 2020. With respect to consumption, in 2019 had a lower consumption than the 49.5 l/km established, as reference and as the pandemic in 2020, the consumption was so decrease.

To achieve improving service reliability estimating the reliable buffer index (RBI). This measure can be calculating by two different definitions: 1-Travel Time Index (TTI), and 2- Planning Time Index (PTI).

Travel Time Index (TTI)

$$TTI = \frac{Average\ travel\ time}{Free\ flow\ travel\ time}$$

Planning Time Index (PTI)

$$PTI = \frac{95\%\ percentile\ travel\ time}{Free\ flow\ travel\ time}$$

Reliable Buffer Index (RBI)

$$RBI = PTI - TTI$$

Figure 1 shows the RBI on a standard week on October for the three years studied. This date was selected since weather conditions are commonly stable and might not interfere in the service reliability. in 2019 Friday and Sunday register the highest values, while in 2021 the highest ones were registered on Monday and Wednesday. An interesting observation can be made between 2019 and 2021 since there is a change in the highest RBIs registered going from weekend to work days.

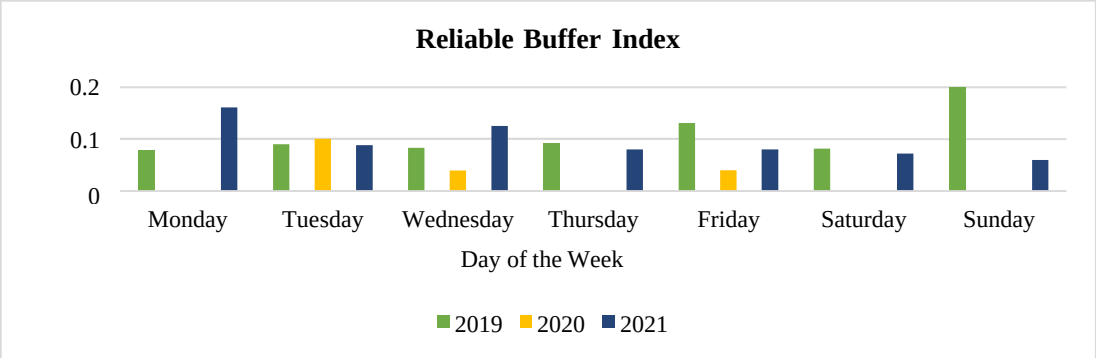

Fig. 1. Reliable Buffer Index in 2019-2020-2021

To increase passenger satisfaction and encourage them to use bus, understanding their opinion is a main way to reach this goal. For reach this result survey is a good way.

A survey campaign was conducted and data were collected in two different time periods in 2021: 1- in August (holiday season), and 2- the last week of October before November 1st (work-days). To obtain a representative sample, more than 2,000 cards were distributed over two weeks, getting a 25% response rate, with a total of 546 valid responses.

Net Promoter Score (NPS) and Customer Satisfaction Score (CS) were selected as the main KPIs to evaluate users' satisfaction.

Net Promoter Score (NPS)

$$NPS = \%Promoters - \%Detractors$$

Customer Satisfaction Score (CS)

$$CS = \frac{Number\ of\ 4,5\ (total\ satisfied) responses}{Total\ number\ of\ responses}$$

*Promoters: Eager to recommend the service to others
*Detractors: Not eager to recommend the service to others

Table 3 shows KPIs estimated based on the results of the survey with data available provided by the operator from a previous survey with similar content conducted in 2019.The result shows that between 2019 and 2021 NPS has increased significantly from 12% to 40% with an increase of 8% in CS too.

Table 3. CS and NPS in 2019-2021

Year	Net Promoter Score (NPS)	Customer Satisfaction Score (CS)
2019 Source: ALSA	12%	70%
2021 Source: TRANSyT survey	40%	78%

To evaluate the performance of the service in the three different modules of TrackBest-3S (safe, sustainable, smart), 5KPIs were estimated. Table 1 shows, VAR and the number of accidents from 2019 to 2021 are decreasing. This reduction can be related to the decrease in number of trips.

Two different approaches were used to evaluate the performance:1-SUMI tools (emissions-pollution) 2- OPTIC Model standard (consumption) for the sustainable module. As a result, the rate of CO2 and PM2.5 in 2020 is lower than in 2019, precisely for the amount of fuel consumption. COVID-19 is a main reason for this reduction.

As previously mentioned, the smart module of the tool is focused on increasing service reliability. Therefore, the Reliability Buffer Index was evaluated for the three years considered. The buffer time index was calculated for each day and explained in Figure 1. BTI values became relatively more significant during the weekends in 2019, and this trend happened on weekdays in 2021. From the figure, it can be e identified that BTI at weekends in 2021 decreased and in total, BTI improved from 2019 to 2021.

The project's goal is to improve the service operation to improve passenger satisfaction. NPS percentage shows passengers' willingness to recommend these services to their friends was improved around 30% from 2019 from 2021. Also, the number of satisfied passengers increased by around 10% between 2019 to 2021. All these KPIs are collected in one dashboard for evaluating all of aspects of objectives. To continue this thesis will sync all data for main tool and create a solution based on results to enhance all the measure.

5.2.4. Al-Akioui, A. Monzon, A. & Cortez, A. (2022). *Boosting bus usage. An analysis of travel behaviour and user satisfaction in Tangier*. 3ème Conférence Internationale Multidisciplinaire : Sciences de l'Environnement et Études Appliquées - ICESAS 2022. 23-25 de mayo de 2022. Tánger, Marruecos.

According to UN-HABITAT (2013), the environmental repercussions of rising motorization are of great concern. In this context, TrackBest-3S arises to optimise the efficiency of bus services by combining safety, sustainability, and reliability. TrackBest-3S focuses on three case studies: two urban areas, Oviedo and Tangier, and the Madrid-Bilbao long-distance line.

Tangier, with nearly one million residents, is experiencing an urban, demographic, and industrial growth. As a result of this, the use of private vehicles is rising deriving in traffic congestion, higher levels of pollution, and more traffic accidents.

Tangier's public transport system consists of a bus network operated by ALSA. It has 45 lines (27 urban and 18 regionals) served by 190 diesel buses. Before the COVID-19 pandemic, the network's use was on the rise, with more than one million kilometres travelled and nearly four million passengers transported per month in 2019.

In addition, improving user perception of the bus is a key step in increasing bus use. A survey campaign with a team of twelve surveyors was conducted in March 2022 to analyse travel behaviour and user satisfaction. Personal interviews were made on buses and in some specific stops.

Six urban lines (2, 9A, 10, 12, 14, 20) and four regional lines (I2, I3, I9, I16) were chosen for two reasons: 1) their high passenger volume (over three million people per month in 2021); and 2) their proximity to major parts of the city. Over 1,300 responses were obtained after seven days of data collection. This work presents an analysis of the obtained results.

5.2.5. Al Suleiman, S., Monzon, A. & Lara, A. (2022). *Towards safer, sustainable, and smart public transport. Oviedo Case Study*. I Jornada Científica en el Programa de Doctorado en Sistemas de Ingeniería Civil - DOSIC 2022. 21 de junio de 2022. Madrid, España.

Urban growth is a worldwide phenomenon which has many side effects. In 2018, 55.3% of the world's population lived in urban areas and this percentage is expected to rise to 60.4% by 2030. Consequently, impacts related to mobility like traffic congestion, GHG and pollutant emissions, traffic accidents are expected to grow.

This research focuses on the city of Oviedo, with 220,000 inhabitants which can be considered a representative sample of medium-sized cities in Spain. Moreover, its public transportation system is mostly based on TUA bus services which is a private company of ALSA Group. The bus network of Oviedo has 15 daytime lines and one night-time line, with a fleet of 67 buses to cover the service. Total ridership in 2019 was some 12 million passengers.

After reviewing previous studies that identified the key factors explaining the overall users´ satisfaction, it was found that little research was done on the satisfaction of urban buses after COVID-19 lockdown and operation with restrictions. This supports the need for this work to determine these factors. The research followed the following steps to achieve the objective of characterizing traveler´s satisfaction during pandemic restrictions.

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I4 was discarded because it was not included in any of the previous factors, and it had a low loading coefficient (smaller than 0.50),

An Ordinal Logistic Regression (Ologit) model was performed to calculate the importance of the 3 identified factors to explain overall satisfaction. The results are the following.

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The *Comfort* factor (1.35) was the most important, while the other two factors, *Service Performance* (0.48) and *Integration* (0.51), showed almost the same importance.

There will be a similar future study for the city of Tangier in Morocco, which is also a medium urban city, with a similar methodology. Then a comparison between the two cities will be performed to analyse which socioeconomic and cultural factors could explain their differences.

5.2.6. Cortez, A., & Monzon, A. (2022). *A multi-dimensional evaluation of urban bus service performance in different contexts. The cases of Oviedo (Spain) and Tangier (Morocco)*. 16th International NECTAR Conference - NECTAR 2022. 20-22 de julio de 2022. Toronto, Canadá.

One of the major issues that cities have to face these days is the constant increase in car ownership and the derived traffic congestion. As a result, the challenge of achieving sustainable and liveable communities is focused on a change in the modal split fostering the use of collective modes of transport. This, together with the fact that buses are one of the most common and accessible means of transport, makes them a key element of the public transport system.

This paper presents a multi-dimensional evaluation of the performance of urban bus systems in two medium-sized cities, Oviedo (Spain) and Tangier (Morocco). Their public transport supply is based on their bus networks. Tangier´s network is made up of 44 lines with a length of 795 km while Oviedo´s network has 16 lines with an extension of 206 km. Moreover, both systems are operated by ALSA company which ensures the availability of comparable data. The analysis combines quantitative data of supply and demand, together with the users' perceived quality of the bus services. To that end, similar surveys were done in both cities, with a common core part and a customized section adapted to the network and socioeconomic characteristics of each of them.

The analysis was done at the macroscopic level to compare supply characteristics and users´ perceptions. The evaluation method is based on the measurement of quantitative and qualitative KPIs grouped into five different categories: service supply, information, comfort and convenience, service usage, and quality of service. There are some 'input´ KPIs that measure the consumption of resources, and some 'output' KPIs to measure the performance of the systems in the five evaluation categories.

First, each city´s system was assessed independently. Then, a qualitative comparison of the overall performance of the two systems was done, considering their differences in population, income, activities, density, frequency, reliability, alternative transport modes (motorization rate), etc.

Results showed that even though both cities and transport systems have very different characteristics, several indicators perform similarly. Both systems have a monthly average of users in urban lines that rounds 125,000 passengers, a capture ratio of 40 people per bus, and a similar bus availability every 1,000 inhabitants (0.22 and 0.30, respectively). However, the multi-dimensional evaluation showed some operational deficiencies in both of them. These gaps, together with improvement areas identified, are being considered in the development of the TrackBest-3S tool which will allow a triple optimization of the bus system operation: safe, sustainable, and smart.

5.2.7. Rahnama, S., Cortez, A., & Monzon, A. (2022). *An expert tool for investigating key explanatory factors for safer bus operation*. 9th Transport Research Arena - TRA 2022. 14-17 de noviembre de 2022. Lisboa, Portugal.

Although buses can be considered one of the safest transport modes, bus safety is crucial and involves operators, passengers, and governments. Bus safety is a critical issue for the relevant implications it generates. From the perspective of Public Transport Companies (PTC), bus accidents increase the costs of an industry that daily deals with high operational costs and low fare revenues (Barabino et al., 2020; Bonera & Maternini, 2020). Much research has focused on identifying patterns of bus accidents to grasp the results of different factors influencing their frequency and severity (Porcu et al., 2021). Analysing the literature on accident data involving buses makes it possible to identify the main causes and factors related to them (Albertsson & Falkmer 2005). Past studies on this subject have been based on aggregate data and were related to different types of buses and bus accident classifications in different countries (Chimba, Sando & Kwigizile, 2010). Different classifications are associated with purpose and use (local buses, transit buses, intercity buses, long-distance buses, etc.) introduce some uncertainty into comparisons of studies based on national accident databases (Albertsson & Falkmer 2005). Furthermore, research has shown that the number of accidents is influenced by factors associated with the weather, traffic, road characteristics and vehicle (Mohammed et al., 2019). Therefore, it is necessary to make a deeper analysis of the bus related accidents with a special focus on long-distance services.

Trackbest-3S investigate long distance bus trip services between Madrid and Bilbao. The purpose of this paper is to find the main factors and the main criteria that influence long-distance bus safe operation.

This research is part of the project TrackBest-3S supported by the R+D+i Spanish Scientific and Technical Research and Innovation plan 2017-2020. The project is coordinated by ALSA, a leading passenger transport company, with the participation of the Transport Research Centre (TRANSyT) of the Polytechnic University of Madrid (UPM). The bus operator ALSA provided data corresponding to long-distance trips between Madrid and Bilbao from 2019 to November 2021. These data include the report of 115 accidents registered by the company in those three years, where buses corresponding to Madrid-Bilbao services were involved. Since the timetable varies between seasons, weekdays and weekends, the analysis was conducted considering all their particularities.

Accidents were classified into four categories according to their main causes: general analysis, weather conditions, accident location (road characteristics) and speed limitation. Assessment of the safety of the road bus considered in this study identified the main factors from each category, looking to explain the importance of each of them. Figure 1 presents the four categories mentioned. Because of this reason, developing a measurement that allows for identifying critical factors is important. The first category is related to analysing the general information about the accidents, for instance:1-the number of accidents that occurred each year, 2- the rate of accidents on weekdays and weekends. For finding the critical weather's type that influences the rate of accidents, choosing the clustering method for each type of weather is a methodology to show the relationship between the accidents and weather's type (Rahimi et al., 2019). In the third step in the speed limitation category, selecting each location and legal speed on there, checking the type of accident, and finally investigating the relation among speed (Lu, 2006), location, and type of accidents. The location of each accident is an essential measure of safety, so dividing each part of the road based on the frequency of accidents and evaluating the high-risk location by using the Standard Hierarchical Model and Hierarchical Ordered Model (Yoon, Kho & Kim, 2017).

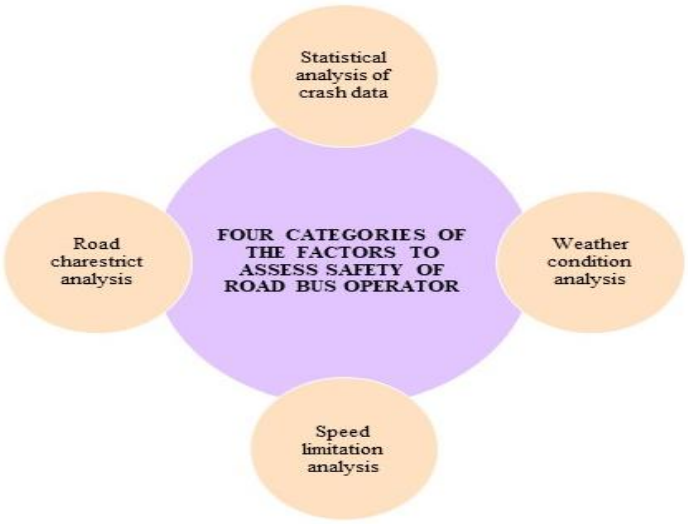

Figure 1. Categories of the models to assess the safety of road bus

Bus accident reports at ALSA data had been studied for many years, coded in several variables and entered into a database. This paper describes the influence of all categories in ALSA accidents. General statistical analysis shows a high percentage of casualties in 2019, and the number of accidents decreased in 2020 because of the COVID-19 limitation. Also during of summer high percentages of accidents were happening. Analysing data shows that most accidents occurred in clear weather and near the terminals in origin and destination.

5.2.8. Al Suleiman, S., Cortez, A., & Monzón, A. (2023). *Evaluation of urban bus service quality in a medium-sized city: Oviedo*. XV Congreso de Ingeniería del Transporte - CIT 2023. 14-16 de junio de 2023. San Cristóbal de la Laguna, España.

The negative effects of mobility, such as traffic congestion, greenhouse gas (GHG) emissions, pollutant emissions, and traffic accidents, are growing as urban travel patterns get more complicated. Promoting the use of public transportation (PT) has become one of the main policy objectives in most countries. To foster a change from private vehicle to PT, it is necessary first to identify the weaknesses and strengths of the PT system through the assessment of users' perception of the services. This study focuses on the bus services of Oviedo (Spain), which can be considered a representative sample of a medium-sized European city. The analysis is based on a survey conducted on passengers to assess their satisfaction with the service and the factors affecting their valuations. A two-step procedure that combines a classification model (CART model) and Importance Performance Analysis (IPA) was used. Results showed that the attributes related to comfort, information, frequency, and schedule on working days are classified as -strong performers-. On the other hand, special attention should be paid to: 'Service start/end time on holidays' and 'Frequency and schedule on holidays and weekends', as they were identified as important attributes with weak performance. The methodology applied allowed us to identify the most important attributes for urban bus users and can serve bus operators in other European medium-sized cities to have a clear overview of where to allocate resources. Results showed that it is necessary to pay extra attention to the service during weekends and holidays.

5.2.9. Cortez, A., & Monzón, A. (2023). *Assessing urban users' satisfaction in Tangier, a developing medium-sized city*. XV Congreso de Ingeniería del Transporte - CIT 2023. 14-16 de junio de 2023. San Cristóbal de la Laguna, España.

The steady rise in car ownership and the resulting negative externalities are some of the biggest problems that cities must deal with. As a result, it is necessary to speed up the shift to sustainable mobility by fostering the use of collective modes of transport. Among the different alternatives, buses are considered the most popular and accessible mode of transport being a vital part of every public transport system. Mobility differs significantly between developing and developed countries, in most developing countries, the private car is the dominant mode due to the low quality of public transport (PT). To achieve the much-needed shift towards sustainable modes, it is essential to assess users´ perceptions of the service. This study focuses on urban bus services of Tangier (Morocco) which is a typical Arab medium-sized city. Moreover, and as in most developing countries, the public transport of this city relays on buses which are the only mode available. Passengers´ satisfaction was assessed through a survey that besides identifying their socioeconomic and trip characteristics, was mainly focused on evaluating their satisfaction with ten service attributes. An Exploratory Factor Analysis (EFA) of the survey data was used to identify key latent factors related to users´ satisfaction that were not directly measured on the questionnaire. In this case, 3 factors were found to be the most important ones: supply, comfort & purchasing, and service hours. Finally, the overall satisfaction (OS) with the service was then explained based on the factors identified using an ordinal logistic regression model that ranks the importance of the attributes identified in the EFA. It was observed that passenger´s satisfaction with service supply and comfort & purchasing is most influential their overall satisfaction.

5.2.10. Rahnama, S., Cortez, A., & Monzón, A. (2023). *Is bus passengers' satisfaction influenced by company's application and website features in long-distance bus service?* XV Congreso de Ingeniería del Transporte - CIT 2023. 14-16 de junio de 2023. San Cristóbal de la Laguna, España.

The bus is the most used and popular mean of public transport in the world. For this, it is essential to measure customer satisfaction to increase the quality level of service. Most studies in the transportation sector have looked at user satisfaction with a company's information channels (website/Mobile app) focused on purchasing tickets. Few studies, however, have examined how the different attributes of the information channels affect users' overall satisfaction (OS) with the service. The intercity line between Madrid and Bilbao was chosen as the case study. Passengers´ satisfaction was assessed through a survey. This data was collected using a hybrid methodology at the Avenida-America interchange in Madrid, which is the origin of the journey between these cities. An ordinal probit regression was used to model how users´ value of different affirmations about information channels´ features affects their OS. The results showed that men prefer to use the website while women are more likely to use the mobile app. In addition, mobile app users are commonly between 18 and 25 years old, while website users tend to be between 36 and 60 years old. Results also showed that the data reliability of both, the mobile app and the web influence the likelihood of OS. In addition, "define preferences of the ticket price for my journey" influences web users' OS. Although web and app users have different profiles, both focused on the same aspects. The insights from this work can help operators to identify the most important attributes of their information channels to increase passenger satisfaction.

5.2.11. Al Suleiman, S., Monzon, A. & Lara, A. (2023). *Evaluation of urban bus service quality in a medium-sized City: Case Study Oviedo*. II Jornada Científica en el Programa de Doctorado en Sistemas de Ingeniería Civil - DOSIC 2023. 29 de junio de 2023. Madrid, España.

The negative effects of mobility, such as traffic congestion, greenhouse gas (GHG) emissions, pollutant emissions, and traffic accidents, are growing as urban travel patterns get more complicated. Promoting the use of public transportation (PT) has become one of the main policy objectives in most countries. To foster a change from private vehicle to PT, it is necessary first to identify the weaknesses and strengths of the PT system through the assessment of users' perception of the services. This study focuses on the bus services of Oviedo (Spain), which can be considered a representative sample of a medium-sized European city. The analysis is based on a survey conducted on passengers to assess their satisfaction with the service and the factors affecting their valuations. A two-step procedure that combines a classification model (CART model) and Importance Performance Analysis (IPA) was used. Results showed that the attributes related to comfort, information, frequency, and schedule on working days are classified as -strong performers-. On the other hand, special attention should be paid to: 'Service start/end time on holidays' and 'Frequency and schedule on holidays and weekends', as they were identified as important attributes with weak performance. The methodology applied allowed us to identify the most important attributes for urban bus users and can serve bus operators in other European medium-sized cities to have a clear overview of where to allocate resources. Results showed that it is necessary to pay extra attention to the service during weekends and holidays.

5.3. Trabajos Fin de Máster y Tesis Doctorales

5.3.1. Pérez Abellán, I. D. (2020). *Optimización de la operación de líneas de autobús urbano mediante gestión dinámica de Big Data. Caso de estudio: Oviedo (Asturias).* Máster Universitario en Ingeniería de Caminos, Canales y Puertos. Universidad Politécnica de Madrid.

La movilidad urbana sostenible, se antoja un reto muy importante que se debe afrontar en las poblaciones del s. XXI, con el fin de proporcionar una solución ante los problemas de congestión de tráfico. Es aquí donde surge la potenciación y mejora del transporte colectivo como una de las principales soluciones para paliar este problema que afecta a cada vez más millones de personas. Dentro de este contexto, el transporte colectivo y más concretamente el autobús, resulta ser un medio de transporte clave a la hora de tratar esta problemática, ya que es un medio que compite en flexibilidad con el automóvil, y en capacidad con el tranvía o medios similares. Alrededor del 60% de la población mundial reside en ciudades, lo cual supone que es en estos lugares donde se producen los principales problemas de congestión por tráfico que dan lugar a grandes pérdidas de tiempo, dinero y, en definitiva, calidad de vida para los ciudadanos. El presente documento, se va a centrar en la movilidad urbana española, y más concretamente en la ciudad de Oviedo, una urbe de alrededor de 220.000 habitantes. La elección de esta ciudad radica en que España es un país que se vertebra en torno a este tipo de poblaciones de medio tamaño, con lo cual algunas de las medidas que se van a desarrollar pueden ser fácilmente extrapolables a otros municipios de tamaño medio que se distribuyen por el territorio. Además, la evolución de la forma de vida de los habitantes de las ciudades, en donde cada vez se da mayor dispersión de lugar de residencia en zonas alejadas del centro urbano, supone que la movilidad urbana se desarrolle de una manera más compleja y se den nuevos retos a los que hay que hacer frente y buscar soluciones.

5.3.2. Al Akioui Sanz, A. (2021). *Optimización de la operación de líneas de autobús mediante gestión dinámica de Big Data. Caso de estudio: Tánger (Marruecos).* Máster Universitario en Ingeniería de Caminos, Canales y Puertos. Universidad Politécnica de Madrid.

Las grandes ciudades del siglo XXI tienen como reto principal reducir la congestión de vehículos y los problemas de tráfico, además de disminuir las emisiones contaminantes, para así conseguir una movilidad más sostenible. Frente a este reto el primer paso que se puede dar es potenciar y mejorar el transporte público colectivo para así reducir el uso del vehículo privado. El presente documento se centrará en el estudio y desarrollo de soluciones de la red de autobuses urbanos y regionales de la ciudad de Tánger, en colaboración con ALSA, operador de la red. Esta ciudad, con casi un millón de habitantes según el Censo de 2014, es la tercera ciudad más poblada del país. La evolución demográfica de la ciudad muestra un gran aumento demográfico en las zonas periféricas de la ciudad, en las cuales se encuentra más del 60% de la población de la ciudad. Además, Tánger es la segunda ciudad industrial más importante de África, con grandes zonas industriales situadas en las afueras de la ciudad. Los hábitos de la población, así como la situación de dispersión de las residencias y centros industriales, hacen que el uso de vehículo privado aumente. Este aumento trae consigo altos niveles de congestión, contaminación y un gran número de accidentes de tráfico. El objetivo principal de este proyecto es la implantación de una triple optimización basada en la fiabilidad del servicio, la sostenibilidad y la seguridad. ALSA proporcionará los datos de operación de su servicio de autobuses, incluyendo datos de demanda y de explotación. A partir de estos datos se propondrán soluciones a la problemática de los desplazamientos urbanos, mejorando la eficiencia y calidad del servicio de transporte público en la ciudad, siempre teniendo como fin último el desarrollo de una movilidad sostenible y segura.

5.3.3. Al Suleiman, A. (2023). *Perceived quality of urban bus services in two medium-sized cities with different contexts: Oviedo and Tangier*. Doctorado en Sistemas de Ingeniería Civil. Universidad Politécnica de Madrid.

Alrededor del 60% de la población mundial vive en ciudades, lo que provoca muchos de los principales problemas de congestión del tráfico, generando grandes pérdidas de tiempo y dinero y, en última instancia, afectando a la calidad de vida de los residentes. La movilidad urbana sostenible parece ser un desafío muy importante que deben afrontar las poblaciones del siglo XXI para dar una solución a los problemas de congestión del tráfico. Aquí, la promoción y mejora del transporte colectivo se plantea como una de las principales soluciones para paliar este problema que afecta a millones de personas.

Una de las políticas clave para superar esos problemas es aumentar el uso del transporte público. En este contexto, el transporte colectivo, y más concretamente el autobús, resulta un medio de transporte clave a la hora de hacer frente a este problema ya que es un medio que compite en flexibilidad con el automóvil y en capacidad con el tranvía u otros medios de transporte, pero deberían ser lo suficientemente atractivos como para cambiar la tendencia hacia el uso del automóvil. Por tanto, mejorar la satisfacción de los usuarios de los servicios de autobús y aumentar el atractivo del autobús juegan un papel fundamental para lograr patrones de movilidad más sostenibles en las áreas urbanas. Además de las referencias bibliográficas, se necesitan opiniones reales de usuarios de autobuses urbanos en ciudades medianas. Por ello, este trabajo de doctorado ha seleccionado dos casos de estudio en dos ciudades medianas diferentes. La primera es la ciudad de Oviedo con 220.000 habitantes, 16 líneas de autobús y una flota de 67 autobuses. El segundo es Tánger con 943.817 habitantes, 45 líneas de autobuses con una flota de 190 autobuses.

Oviedo y Tánger fueron seleccionadas para este estudio como casos correspondientes a contextos socioeconómicos, culturales y geográficos muy diferentes. Oviedo representa una ciudad europea con un sistema de transporte público relativamente bien desarrollado, mientras que Tánger es una ciudad del norte de África con desafíos urbanos únicos. Esta diversidad permite un análisis más completo. El principal objetivo de la tesis es identificar los factores clave que afectan la satisfacción de los usuarios de autobuses urbanos, así como identificar la importancia de los atributos que explican la calidad percibida en cada uno de los casos y sus diferencias. Se realizaron dos campañas de encuestas en los dos casos de estudio. En Oviedo se realizó una encuesta entre el 15 y el 19 de noviembre de 2021 con un total de 970 respuestas válidas. En Tánger se realizó una encuesta entre el 25 y el 31 de marzo de 2022 con un total de 1271 respuestas válidas.

El análisis comparativo de los factores y atributos que afectan a los usuarios de autobuses urbanos en Oviedo y Tánger permitió definir diferencias y similitudes, y discutir y comparar los resultados entre una ciudad desarrollada y una en desarrollo. Los principales hallazgos indican la presencia de similitudes y diferencias en los factores que contribuyen a aumentar la satisfacción de los usuarios de autobuses urbanos. Asimismo, existen diferencias significativas en la calidad percibida de los servicios de autobús urbano entre Oviedo y Tánger; mientras que Oviedo generalmente obtuvo una puntuación más alta en calidad percibida, Tánger mostró potencial de mejora con intervenciones específicas, donde los factores como la situación económica, los factores socioeconómicos y las preferencias culturales influyen en estos resultados. Finalmente, se proponen algunas recomendaciones para que los operadores de transporte y los decisores públicos adapten estrategias para satisfacer las necesidades específicas de cada ciudad, lograr mayores niveles de satisfacción y mejorar la calidad percibida para mejorar la sostenibilidad de la movilidad urbana.

5.4. Entregables del Proyecto

5.4.1. Cortez, A., & Al-Akioui, A. *Entregable 0.0 Motivación y Objetivos del Proyecto*.

Documento que contiene la motivación y los objetivos del proyecto.

5.4.2. Cortez, A., & Al-Akioui, A. *Entregable 0.1.1 Informe Anual 2020.*

Documento justificativo que describe las tareas y fases realizadas en el año 2020.

5.4.3. Cortez, A., & Al-Akioui, A. *Entregable 0.1.2 Informe Anual 2021*.

Documento justificativo que describe las tareas y fases realizadas en el año 2021.

5.4.4. Cortez, A., & Al-Akioui, A. *Entregable 0.2 Informe Final.*

Documento resumen de las fases y tareas realizadas al final del proyecto.

5.4.5. Cortez, A., Al-Akioui, A., Rahnama, S., & Aldanondo N. *Entregable 1.1 Informe de Análisis Técnico y de Mercado.*

Informe con la evaluación de experiencias previas ya implementadas y los factores y la tecnología más relevante del estado del arte.

5.4.6. Cortez, A., Al-Akioui, A., & Pérez, I. *Entregable 2.1 Marco Tecnológico.*

Documento que recoge la selección de fuentes de datos para el desarrollo de TrackBest-3S, así como las acciones llevadas a cabo para su integración en las herramientas de visualización existentes en ALSA.

5.4.7. Cortez, A., Al-Akioui, A., Rahnama, S. *Entregable 2.2 Base de Datos.*

Base de datos relacional implementada para el desarrollo de TrackBest-3S.

5.4.8. Aldanondo, N. *Entregable 3.1 Software TrackBest-3S.*

Software basado en tres módulos que permite la gestión inteligente de flotas de autobús.

5.4.9. Cortez, A., Al-Akioui, A., Rahnama, S. *Entregable 3.2 Especificaciones Técnicas de TrackBest-3S.*

Documento que indica las especificaciones y modo de funcionamiento del software.

5.4.10. Cortez, A., Al-Akioui, A., Pérez, I. *Entregable 4.1 Diagnóstico Inicial de los Casos de Estudios.*

Documento que recoge la situación inicial de los casos de estudio.

5.4.11. Cortez, A., Al-Akioui, A., & López, J. *Livrable 4.1 Diagnostic Initial du Cas d'Étude de Tanger.*

Documento que recoge la situación inicial del caso de estudio de Tánger.

5.4.12. Cortez, A., Al-Akioui, A., & Rahnama, S. *Entregable 4.2 Informe de Evaluación de los Módulos.*

Informe que recoge la metodología de evaluación cuantitativa de cada módulo y los resultados en base a indicadores.

5.4.13. Cortez, A., Al-Akioui, A., & Rahnama, S. *Entregable 4.3 Informe de Evaluación Integral.*

Documento de evaluación integral de TrackBest-3S: cuantitativa y cualitativa.

5.4.14. Cortez, A., & Al-Akioui, A. *Entregable 5.1 Informe de Calidad Percibida.*

Informe de calidad percibida por usuarios y conductores basado en encuestas realizadas.

5.4.15. Cortez, A., & Al-Akioui, A. *Entregable 5.2 Informe de Impactos.*

Documento que recoge los impactos sociales, ambientales y económicos producidos por TrackBest-3S.

5.4.16. Aldanondo, N. *Entregable 5.3 Modelo de Utilidad.*

Documento que recoge la definición y características del modelo de utilidad producido en el proyecto.

5.4.17. Aldanondo, N. *Entregable 5.4 Plan de Negocio y Comercial.*

Informe que incluirá el análisis del mercado, los clientes y la competencia y los canales a utilizar para realizar la venta del producto generado.

5.4.18. Cortez, A., Al-Akioui, A., Monzón, A., Rahnama, S., Al Suleiman, S., López, J., Aldanondo, N., Pérez, I., & Lara, A. *Entregable 5.5 Plan de Difusión de la Innovación.*

Documento donde se detallará el listado de publicaciones y contribuciones en los distintos ámbitos científicos del proyecto.

5.4.19. Aldanondo, N. *Entregable 5.6 Plan de Internacionalización.*

Documento que recoge la estrategia de internacionalización del producto, incluyendo mercados clave y convocatorias competitivas de innovación.

6. FINANCIACIÓN

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7. REFERENCIAS

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