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New challenges in cartography – mapping in autonomous transport systems

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Summary

The paper presents the results of research on the role of cartographic products and high-definition (HD) mapping in the autonomous vehicle industry. The research methodology includes a review of professional literature and a qualitative interview with an expert from the autonomous transport industry (Blees company). Blees, founded in 2019, specializes in autonomous minibuses, which aim to ensure safe and fast passenger transportation. The company implements advanced and broad transport implementations in cities and municipalities, including Gliwice, Jaworzno, and Sosnowiec. The analysis covers the characteristics of automation levels according to the SAE J3016 standard and technical specifications of sensors, such as LiDAR, RADAR, and GNSS-RTK. A synthetic review of industry applications (TomTom RoadDNA, HERE HD Live Map) and technological solutions was performed with particular emphasis on the SLAM algorithm and Digital Twin Cities concept. The study confirms that contemporary cartography has evolved from human-centred representations into a digital foundation for machine perception, providing a 'virtual sensor' for precise localization and safe driving. The results are presented in reference to the practical experiences of the Blees BB-1 autonomous minibus deployment. Cartography has become the digital foundation for perception of autonomous systems. HD maps serve as a virtual sensor with an unlimited field of view. The SLAM algorithm enables navigation in the absence of satellite signals. 128-beam LiDAR allows for mapping of road geometry with a precision down to once centimetre. Precise spatial data supports environmental sustainability and the smooth flow of urban traffic.

Keywords

autonomous vehicles • HD mapping • contemporary cartography • sustainable transport • SLAM • mobile mapping

1. Introduction

The evolution of modern cartography from a traditional discipline focused on the graphic representation of terrain towards a dynamic, digital foundation for autonomous systems marks one of the most significant breakthroughs in the field of spatial information science [Zygmunt 2025]. Traditional maps, designed over the centuries to meet human perception, relied on a high level of generalisation, allowing the user to orientate themselves with their own cognitive abilities. However, in the era of the Fourth Industrial Revolution and the development of smart cities, it is machines that become the receivers of data – decision-making algorithms requiring information several orders of magnitude more precise than human can absorb [Choromański et al. 2020].

High-definition (HD) maps and the concept of Digital Twin Cities provide the foundation for today's navigation systems. The aim of this paper is to analyse the role of cartography in the development of autonomous navigation and to verify whether precise cartographic products are an essential link in the transport safety chain of the future, exceeding the capabilities of standard onboard sensors.

2. Materials and methods

The research methodology was based on a two-step analysis. The first step involved a review of the specialist literature and technical documentation from key providers of geoinformation solutions (HERE, TomTom, Robosense). The second step was an in-depth interview with an expert from Blees, a company specialising in autonomous transport systems. The analysis integrates theoretical knowledge with practical experience of implementing the Blees BB-1 vehicle in urban conditions.

3. Results and discussion

3.1. Classification of automation levels and the role of spatial data

To understand the role of cartography for the purposes of this study, it is necessary to refer to the SAE standard, which defines six levels of automated driving (Table 1). The data contained therein shows that at Levels 4 and 5, the HD map is no longer merely a support tool, but becomes a crucial element of safety, enabling the achievement of the so-called *Minimal Risk Condition* (MRC) – the safe stopping of the vehicle in the event of sensor failure.

The abbreviation ADAS used in Table 1 stands for Advanced Driver Assistance Systems. These are electronic systems installed in vehicles to assist the driver and to improve road safety. Typical ADAS functions include: adaptive cruise control, which adjusts speed to the vehicle ahead; lane-keeping assistance, which corrects the vehicle's trajectory; traffic sign recognition systems; and Intelligent Speed Assistance (ISA). ADAS maps provide autonomous vehicles with precise data on road geometry (e.g. terrain gradient, bend radii), allowing onboard systems to respond to road conditions even before they are detected by the vehicle's physical sensors, such as cameras or radars.

Table 1. The role of positioning systems and maps across SAE automation levels

SAE level	Automation degree	Range of automation	Functional description	The role of maps and positioning
0	Lack	Human performs all operations	The driver monitors the surroundings; the systems support movement	Static maps (2D) or ADAS (curvature, slope)
1	Assistance	Individual systems (e.g. cruise control)		
2	Partial automation	Lane-keeping assistance and speed control		
3	Conditional automation	System monitors the surroundings	The system monitors the surroundings; the driver must be ready to take control	HD maps as the base for perception and maneuver planning
4	High automation	Autonomous driving in the domain (ODD)	The vehicle performs tasks in specific domains (ODD) without human intervention	HD maps with real-time data; essential for MRC
5	Full automation	No restrictions by surroundings	Full automation without ODD restrictions	Dynamic, global world model; full data redundancy

Source: developed based on SAE

The abbreviation ODD used in Table 1 refers to Operational Design Domain. This is a key concept in the classification of levels of vehicle automation. ODD describes the specific conditions under which a given automated driving system is designed to operate safely. This domain defines the limits of the machine's capabilities and may include the following factors: environmental (e.g. driving only in good weather, no snowfall or dense fog), infrastructural (e.g. travelling exclusively on motorways, specific urban routes or within a designated campus), temporal (e.g. driving only during daylight hours) and other parameters (e.g. speed limits to a specific value – 35 km/h in the case of the Blees minibus). As shown in the data in Table 1, ODD plays the least significant role in SAE automation levels 4 and 5. Level 4 is characterised by a high degree of automation. The vehicle can operate fully autonomously, but only within its designated domain (ODD). If the vehicle leaves the designated area or weather conditions deteriorate drastically, the system must be able to independently transition to a safe state (MRC), e.g. pull over, if the driver does not retake control. In the case of Level 5, where full automation is achieved, the concept of ODD ceases to exist. The vehicle must be capable of operating anywhere a human could, without any operational domain restrictions.

3.2. Perception and sensory systems: integration with the HD map

An autonomous vehicle interprets the world by fusing data from internal sensors (odometry, IMU) and external sensors (LiDAR, radar, cameras). The role of cartography is to provide *a priori* knowledge that allows filtering out sensor noise and focusing on relevant road features [Choromański et al. 2020]. As explained by an expert from Blees, odometry is a method of determining a vehicle's position and orientation based on motion data from onboard sensors. In transport systems, the vehicle's trajectory is determined by summing the rotational speeds of the wheels. This speed is usually measured using encoders (rotary-pulse optical or magnetic sensors). Odometry provides information on the vehicle's relative displacement. Its advantage is that it is completely independent of external conditions and the environment (e.g. lack of lighting or lack of landmarks), which makes it the foundation of local positioning. The expert also outlined the disadvantages of odometry. The main problem is the accumulation of measurement errors over time (so-called drift), caused, for example, by wheel slip or uneven terrain, which can lead to increasing positioning inaccuracy if not corrected by other sources. Meanwhile, an IMU (Inertial Measurement Unit) is an electronic module used to measure inertial forces and the vehicle's orientation in three-dimensional space. The IMU ensures continuous navigation in situations where the GNSS signal is temporarily unavailable (e.g. in tunnels or under viaducts) or when visual sensors (LiDAR, cameras) are unable to maintain orientation in a homogeneous environment. In advanced systems, such as the Blees BB-1 minibus, odometry and IMU data are fused. This enables the prediction of the vehicle's position, ensuring safety and a smooth ride even in the event of a temporary disruption to the main positioning systems.

Modern LiDAR sensors, such as the Robosense Ruby Plus, generate precise point clouds, offering 128 laser beams and a range of up to 240 m. The use of GPS-RTK technology in combination with IMU units ensures continuous navigation with centimetre-level accuracy, even in so-called urban canyons. Table 2 provides an overview of the most important sensors used in autonomous vehicle navigation. The compiled data clearly shows that camera and LiDAR sensors are the most susceptible to weather conditions and terrain obstacles.

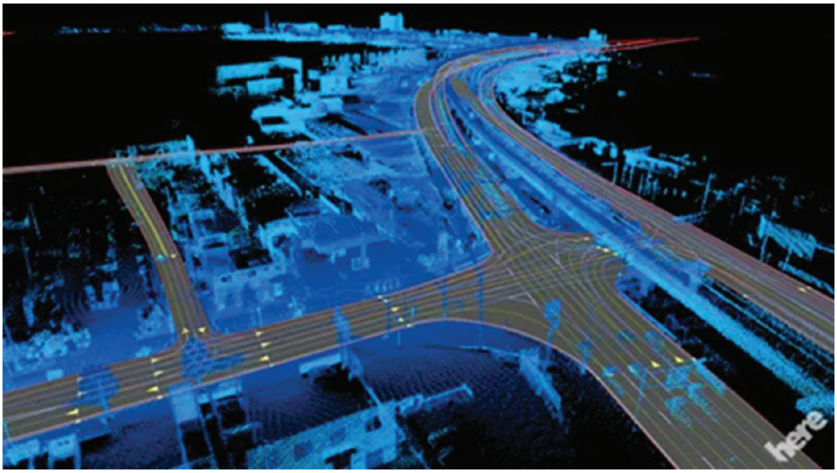
Table 2. Characteristics of sensors in autonomous navigation

Sensor type	Main advantages in navigation	Susceptibility to weather conditions and terrain obstacles
LiDAR	Precise 3D geometry; independence from light	High (fog and snow scatter the beam)
RADAR	Speed measurement; weather resistant	Low (poor resolution)
CAMERAS	Color recognition (traffic lights) and sign recognition	Very high (blindness, precipitation)
GNSS/RTK	Positioning in global system (eg. 1992)	Medium (tunnels, dense development)

Source: developed based on Brzozowski [2022]

3.3. Industrial solutions: HD maps and SLAM algorithms

According to a review of the scientific literature, TomTom and HERE offer commercial HD maps with an accuracy of 5–20 cm. TomTom's RoadDNA technology compresses three-dimensional environmental models into an optimised 2D layer, minimising the vehicle's computational requirements. RoadDNA comprises dedicated layers: Roadside (for LiDAR), Signs and Markings (for cameras). The development of autonomous vehicles beyond advanced sensor systems requires support in the form of precise data on roads and surroundings. By using laser measurements and time-based methods that rely on the reflection of waves from obstacles (using the Doppler effect), it is possible to obtain a three-dimensional visualisation of roads and infrastructure with an accuracy of 10–20 centimetres. By scanning the road surface across the entire width of the roadway, the system provides key information on road conditions, such as the location of potholes, roadworks or changes to traffic organisation. With this data, autonomous vehicles can not only avoid dangers, but also plan their routes more effectively. Thanks to its innovations, Here has helped accelerate the roll-out of autonomous vehicles on the global market. Precise 3D maps not only support navigation but also enhance safety and enable smoother traffic flow in complex road environments. An example of such a map is shown in Figure 1.



Source: https://spidersweb.pl/wp-content/uploads/2015/07/here-3d-maps.jpg

Fig. 1. 3D map by HERE

In areas of dense, high-rise development, in situations where there is no GNSS signal or the map is out of date, the SLAM (*Simultaneous Localisation and Mapping*) algorithm becomes essential. It enables the simultaneous mapping of an unknown environment and self-localisation within it through the analysis of *landmarks* [Choromański et al. 2020].

3.4. Case study: The Blees BB-1 autonomous minibus

As a pioneer in the Polish autonomous public transport market, Blees provides valuable data on the practical implementation of mapping technology in urban traffic. Their BB-1 minibus project addresses the issues of transport exclusion and aims to optimise the operating costs of less popular routes.

The process of creating and updating HD maps in Blees

According to information obtained from company experts, the process of deploying a vehicle on a new route begins with a series of test runs with a vehicle equipped with a 128-beam LiDAR. Key parameters of this process include:

1. Mapping speed: 5–7 km/h, which allows for generating maximum point cloud density.
2. Positioning technology: Utilizing GPS-RTK to ensure compliance with global coordinate systems.
3. Map structure: Overlaying lanelets (logical movement paths) onto the raw point cloud in PCD (Point Cloud Data) format.
4. Update frequency: Currently, maps are refreshed on average once every six months, but in dynamic urban traffic, it is planned to introduce SLAM systems enabling real-time map updates.

In situations where location accuracy is compromised (e.g., under dense tree canopy or in tunnels), the Blees system uses position prediction based on odometry and steering angle. This approach affords the redundancy necessary for passenger safety.

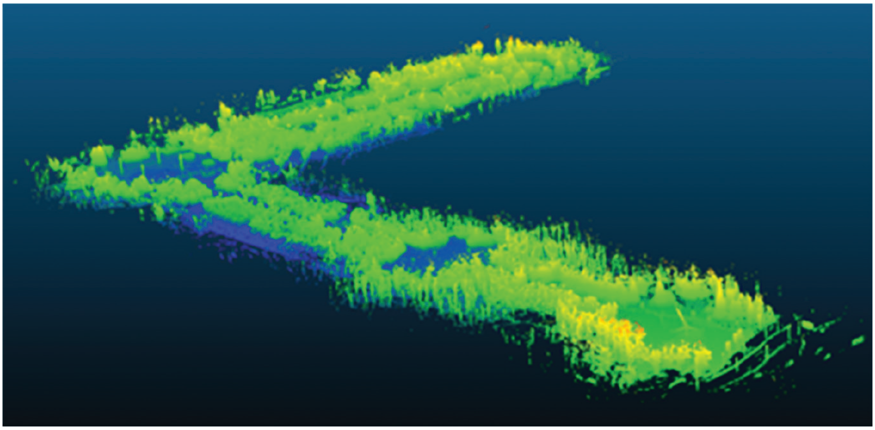
Advanced SLAM systems utilize various filtering techniques, such as Kalman Filters (including the Extended Kalman Filter (EKF)) and Particle Filters. The process can be described as a cycle of prediction and correction:

1. The system predicts the vehicle's new position based on odometry (number of wheel revolutions) and IMU.
2. Sensors (LiDAR or cameras) observe the surroundings.
3. The algorithm compares the observed objects with those stored in the temporary map.
4. Based on the difference (innovation error), the vehicle position is corrected and the map geometry is updated.

Figure 2 shows an example point cloud generated for the needs of Blees.

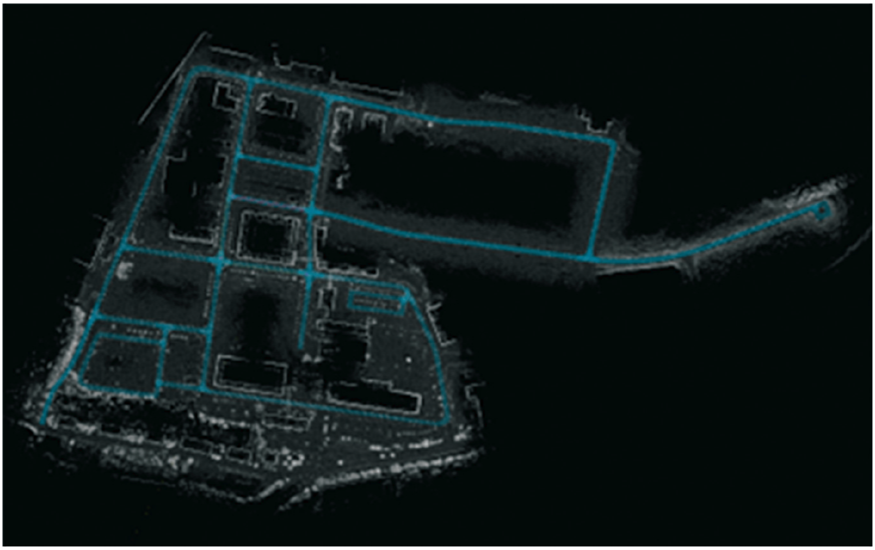
During the localization process, logical layers (lanelets) are applied to the raw point cloud (PCD format) in order to define vehicle paths. The subsequent stages of data processing for map creation are shown in Figures 3 and 4.

The Blees expert pointed out the reason why HD maps are updated on average once every six months. The main challenges remain the limited computing power of process stations and the need to maintain data privacy in sensitive areas.



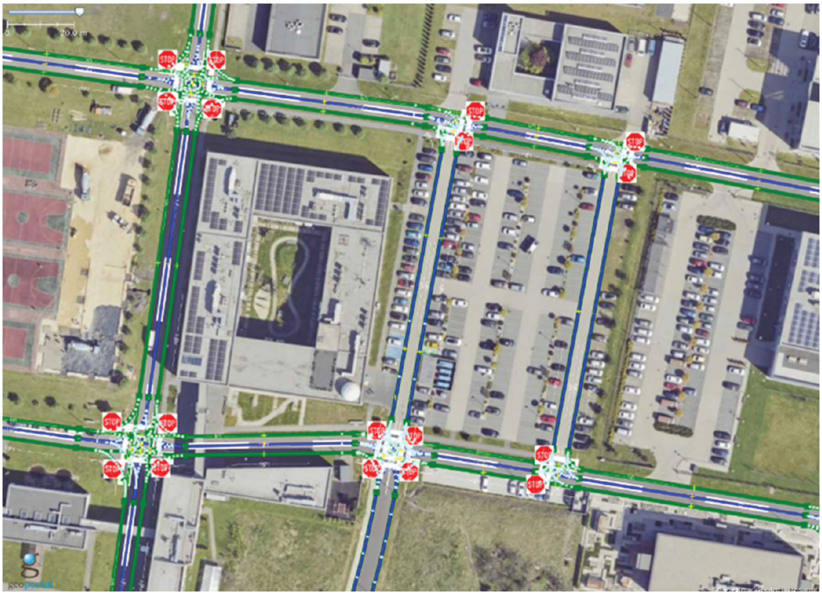
Source: https://blees.co/wp-content/uploads/2023/10/raw_map_blees.jpg

Fig. 2. Raw point cloud generated for the terrain of Park Śląski



Source: https://blees.co/wp-content/uploads/2023/10/rviz_map_blees.jpg

Fig. 3. PCD and OSM map of the given area in RViz



Source: https://blees.co/wp-content/uploads/2023/10/josm_map_blees.jpg

Fig. 4. OSM map displayed in JOSM

Social, legal and ecological challenges for autonomous cartography

The implementation of autonomous vehicles is not only associated with technological barriers but also with the need to meet the legal framework and ensure social acceptance. Sustainable development and environmental protection are increasingly addressed in GLL's scientific publications. HD mapping directly contributes to reducing exhaust emissions by optimizing routes and smoothing traffic (eliminating sudden accelerations and braking).

However, as the results of an interview with a Blees expert revealed, technological advancements pose challenges regarding data privacy. Mobile scanners capture vast amounts of information about the surroundings, which could lead to future legal conflicts in sensitive areas such as military sites or private properties. The lack of uniform standards and norms related to the accuracy and use of HD maps forces manufacturers to use proprietary, often incompatible solutions.

4. Conclusions

1. High-resolution cartography has evolved into the high-tech discipline of 'big data,' which is an essential link in the decision-making chain of autonomous vehicles.
2. HD maps serve as a 'virtual sensor' with unlimited range, enabling algorithms to predict road infrastructure (e.g., curves, traffic lights) before they are detected by onboard sensors.

3. The integration of SLAM technology with HD maps and GNSS-RTK positioning affords the redundancy necessary for passenger safety, as confirmed by the high ratings of the subjective feeling of safety of users (8.5/10) in Blees tests.
4. Further development of this field will be coupled with the construction of digital twins of urban areas, which will contribute to traffic optimization and the achievement of sustainable development goals.

References

Blees. 2025. Interview with an expert in autonomous systems (unpublished). Internal materials of Blees company. Gliwice.

Brzozowski M. 2022. Samochody autonomiczne, sensory otoczenia i problemy percepcji. Wydawnictwo Akademii Techniczno-Humanistycznej, Bielsko-Biała.

Chiang K.W., Tsai M.L., Chu C.H. 2022. Bending the Curve of HD Maps Production for Autonomous Vehicle Applications in Taiwan. IEEE Access, 10, 98880–98895. https://doi.org/10.1109/ACCESS.2022.3204561

Choromański W., Grabarek I., Kozłowski M., Czerepicki A., Marczuk K. 2020. Pojazdy autonomiczne i systemy transportu autonomicznego. Wydawnictwo Naukowe PWN, Warszawa.

HERE. 2025. HERE HD Live Map: Precision and scale for automated driving. https://www.here.com/platform/hd-live-map [accessed: 15.01.2025].

Robosense. 2024. Robosense Ruby Plus: Enhanced 128-Beam LiDAR for L4 Autonomous Vehicles – Brochure. Robosense, Shenzhen.

SAE International. 2021. Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles (J3016_202104). SAE International, Warrendale, PA.

TomTom. 2024. TomTom RoadDNA: Robust and scalable localization technology – Product Sheet. TomTom NV, Amsterdam.

Zygmunt M. 2025. Spatial indexing in access to cartographic archives for GIS/AI systems: A case study of ULK (Krakow Local System). Geomatics, Landmanagement and Landscape, 3, 131–146. https://doi.org/10.15576/GLL/210198