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Mitigating Gender-Based Risks in Last-Mile Logistics through GPS Tracking and Safety Intervention for Female Delivery Workers

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Abstract. The perception of insecurity among women represents an obstacle to their participation in the last-mile delivery sector. A survey of approximately 100 women was conducted to establish a diagnosis, with 85.4% identifying the risk of experiencing harassment or violence during delivery activities as a determining factor when considering this type of employment. Various commercially available GPS devices were analysed, leading to the selection of one with low operating costs and a combination of technical and functional characteristics considered appropriate for delivery activities. In addition, a protocol for assisting female delivery workers was proposed. The proposal includes indicators intended to assess social and economic impact, with the aim of supporting increased female participation. The results suggest that the implementation of tracking technology could mitigate the perception of insecurity and may contribute to the development of safer and more inclusive work environments.
Keywords: Last mile, female delivery workers, tracking systems, sustainability, logistics 5.0.

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1 Introduction

Due to the growth of e-commerce, last-mile logistics has become an essential component of modern supply chains (Boysen et al., 2021; Raj et al., 2023), offering job flexibility, low entry barriers, and relatively appropriate pay (Díaz & Aparicio, 2024). Although awareness is growing, marked gender inequalities persist within the logistics and transportation sector, and female participation in this sector accounts for less than 20% in Mexico. This persistent gender gap is not a mere social limitation but also a significant economic loss (Cuberes & Teignier, 2018; World Bank, 2020). A primary driver of this inequality is the perception of insecurity, deterring many women from pursuing this type of work activity (Alba Vega et al., 2024). Fraszczyk and Piip (2019) identify other structural factors, such as wage disparities, unequal responsibilities, poor work-life balance, as well as stereotypes and gender violence, hindering female inclusion in the logistics and supply chain industry.

Yang et al. (2024) found significant differences between professionals' perceptions and actual reality regarding gender equality in the logistics sector. Although women's empowerment is considered an effective tool for reducing poverty (Plambeck & Ramdas, 2020), women are overrepresented in informal jobs, often without social protection, but are underrepresented in decision-making positions (Mahdawi & Evans, 2022). One of the options to increase women's opportunities and reduce gender inequality in labor markets is the use of contemporary technology (Subramanıan et al., 2024). By integrating technology into traditionally male-dominated fields, such as logistics, new opportunities for women's employment and empowerment can be created, providing them with the tools and skills required for more secure, flexible, and accessible work.

Given the previous scenario, this research proposes a specific technological solution, considering initiatives such as the *Programa Integral de Seguridad Vial 2021-202* (Comprehensive Road Safety Program 2021-2024; SEMOVI, 2021) and the la *Ley General de Movilidad y Seguridad Vial* (General Law on Mobility and Road Safety) proposed by the Centro de Estudios Legislativos para la Igualdad de Género (CELIG, 2025) of the Congreso de la Ciudad de México. The proposed solution consists of the implementation of low-cost GPS devices, appropriate for the working conditions and safety needs of delivery workers. This proposal is aligned with the principles of Logistics 5.0, which promotes the integration of smart technologies with a vision oriented towards inclusion and social equity. Likewise, it is aligned with the Sustainable Development Goals promulgated by the UN (https://www.un.org/sustainabledevelopment/), specifically 5 (Gender equality), 8 (Decent work and economic growth), and 10 (Reduced inequalities). The methodology in this work combined three key components: a quantitative assessment using surveys

of 100 women, a technical and economic analysis of devices available on the Mexican market, and the proposal of indicators to evaluate social and economic impact.

2 Literature review

This research is based on the theory of spatial justice (Soja, 2010). This theory, coined by Soja (2010) and based on the conceptualization of the right to the city (Lefebvre, 1968), emphasizes the equitable right of urban dwellers to the services and sociopolitical structures of a city, emphasizing how geographic factors influence equity and access (Pereira et al., 2017). This theory allows us to analyze how androcentric design, accessibility, and insecurity disproportionately affect women, impairing their right to occupy public space. Improvements from this perspective, specifically regarding gender equity in jobs in logistics chains, can include designing routes that consider the activities and location of working mothers, improving surveillance, implementing control elements at specific points, etc. The dynamic geofencing protocol presented in this paper operates as a corrective mechanism for the current spatial injustice perceived by women in last-mile work.

This section summarizes the literature on female participation in last-mile logistics. The security protocol presented in this paper aims at increasing the female participation in the last-mile delivery activity and is based on the aspects illustrated in Fig. 1. It is structured around three fundamental themes: the literature review, the research methodology, and the operational components of the protocol.

Fig. 1. Schematic representation of the bibliographic analysis

The literature review identified key themes that serve as the basis for the proposed protocol. These include the operational challenges women face in their inclusion in the field of last-mile logistics, the structural and cultural barriers to their integration in this sector, and best practices derived from occupational safety protocols. These elements allow for the identification of the factors that limit female participation. The methodology is composed of three core aspects: diagnostics, using Likert-type surveys to identify women's perceptions of safety in the field of last-mile logistics; the technical selection of GPS devices, which considers cost, battery life, and ease of use; and the proposed evaluation of the protocol's impact in terms of incident reduction, increased female participation and perceptions of safety.

2.1 Last-mile logistics

Supply chains are systems that integrate companies to collaborate in a coordinated manner, in order to take advantage of emerging market opportunities and in this way meet specific customer needs. The final link in the supply chain is called the "last mile" (Carreño, 2018; Boysen, Fedtke, & Schwerdfeger, 2021) and refers to the final stretch of product delivery from a distribution center or point of sale to the customer's destination. The last mile is a critical moment that defines the customer experience and concentrates a large part of the logistical challenges, such as urban congestion, delivery timeliness, security, customer satisfaction with the product/service, among others. This stage is considered one of the costliest, least efficient, and most polluting in the entire logistics chain (Gevaers et al., 2014). Therefore, its efficient management has become a key component to ensure the competitiveness and good performance of the logistics system.

2.2 Female participation in last-mile logistics

An important assertion made by several authors to understand the importance of women's participation in the labor market is that if working-aged women who are not participating in the labor market did so in the same proportion as their counterparts, there would be a gain equivalent to 22% of Mexico's per capita GDP (Cuberes & Teignier, 2018; World Bank, 2020). Women's participation in last-mile work is perceived to be low compared to that of men (Nigam, 2010; Reynolds, 2024). One of the questions that arise in this regard is why female participation in the last mile is so low, despite the important working hour flexibility, specifically favorable for women, given the household care activities they generally must attend to? Evidence points to the existence of structural and cultural barriers in this regard. Fraszczyk & Piip (2019) and Nigam (2010) identify a patriarchal workplace culture, legal restrictions on women's working time, limited maternity protection, wage disparities, unequal opportunities and responsibilities, lack of corporate work-life balance initiatives, and the existence of stereotypes, violence, harassment, and bullying as barriers for women to join the logistics and supply chain (L&SC) industry. These transport-related barriers do not only affect women's job choices but also other aspects of their lives (González et al., 2023). According to the *Unidad de Inteligencia y de Mercado Laboral* (Labor Market Intelligence Unit, UIMEL, 2023), women working for certain delivery platforms face specific challenges, such as a lack of suitable workplaces, sexual harassment and violence by platform users, and exposure to dangerous situations when working alone in urban areas. Furthermore, freight drivers are generally considered to require physical strength, flexibility, and driving skills, with these characteristics being attributed to men but not necessarily to women (Hopkins & Akyelken, 2022; Yousuf & Majid, 2023).

During the COVID-19 pandemic, home delivery became a crucial career option. Although this activity offers advantages such as flexible hours, these characteristics do not compensate for the physical risks or the constant perception of insecurity, which is why delivery work hasn’t been an attractive option to many women (Cortez Oviedo et al., 2023; Rubery et al., 2024; Singh, 2024). This perception of danger is reflected in the fact that 16% of women are accompanied by another person during delivery activities (Alba Vega & Aparicio López, 2022). Women consider delivery work riskier because it involves constantly traveling to generally unknown addresses. Among the main concerns that discourage their participation in this field are nighttime deliveries, due to exposure to theft or sexual violence, working in dangerous areas, and traffic accidents. Furthermore, 20% of surveyed the women who work in the delivery area report having experienced sexual harassment during their workday, either by customers or coworkers (Alba Vega & Aparicio López, 2024). These data show that today´s inclusion of women in the last-mile workforce is not favored by organizational and social factors.

2.3 Safety protocols for female participation in the workplace

Barba (2023) points out that cargo transportation security protocols must incorporate key elements that allow for a rapid response in risky situations. This kind of event often generates high levels of pressure and stress to the individual, so it is essential for companies to provide transportation personnel with the necessary tools and establish standardized processes that ensure effective execution of the protocol, regardless of who implements it. Among the recommended tools are GPS devices, which allow real-time monitoring of vehicles and personnel, constituting in this way a valuable resource for preventing and responding to incidents. The article also recommends companies to have an updated list of emergency contacts, such as security forces, medical services, and civil protection, in order to facilitate a rapid response to any eventuality.

The *Programa de apoyo a las instancias de mujeres en las entidades federativas* (Support Program for Women's Organizations in the Federal Entities), proposed by the Mexican Secretaría de las Mujeres (SEMUJERES, 2024), aims to foster cultural changes that favor the construction of inclusive and violence-free environments, promoting the implementation of talks, workshops, and other training activities.

The *Camina libre, camina segura* (Walk free, walk safe) project of the Secretaría de Movilidad de la Ciudad de México (SEMOVI, 2021) includes maintenance and improvement actions in public spaces to increase safety, particularly for women. Among the measures included in this project are increased lighting in priority areas, the regeneration of the urban environment, and the installation of emergency buttons and video surveillance cameras. These actions are intended to be strategically implemented at key points for women's daily mobility, promoting safer journeys.

Based on the analysis of the challenges and pending issues regarding gender equality and women's access to a life free of violence faced in Mexico City, the new *Ley general de movilidad y seguridad vial* (General Law on Mobility and Road Safety, CELIG, 2025) addresses the challenges faced by women in the area of urban mobility. Its objective is to provide technical input for harmonizing the *Ley de Movilidad de la Ciudad de México* (Mexico City Mobility Law), incorporating a gender perspective. Its

main findings include the existence of violence and harassment in public transportation, especially against women. It highlights the need of

- recognizing the need of care-related travel, and address it through policies that facilitate these journeys,
- road safety with a gender perspective, which proposes incorporating gender criteria into the planning and design of road infrastructure,
- considering the different needs and mobility patterns of women and men, and
- planning instruments for gender equality, which recommends institutionalizing mechanisms to guarantee the mainstreaming of the gender perspective in mobility policies and programs.

The *Modelo de protocolo para prevenir, atender y erradicar la violencia laboral en los centros de trabajo* (Protocol model for preventing, addressing, and eradicating labor violence workplace in the workplace, Secretaría del Trabajo y Previsión Social (STPS, 2020) establishes the actions for implementing the corresponding procedures, including workplace bullying, harassment, and sexual harassment. It proposes to design strategic actors to facilitate the implemention of the protocol, such as a counselor responsible for guiding and supporting the alleged victim, and an assistance and monitoring committee. Likewise, the protocol includes mechanisms for obtaining assistance in one of the existing conciliation centers, as well as protective measures that foster a safe and appropriate environment for the victim.

The *Protocolo para detectar, atender y acompañar a personas usuarias en casos de hostigamiento y acoso sexual/laboral* (Protocol for detecting, assisting, and supporting users in cases of sexual/workplace harassment and bullying), developed by the Procuraduría Federal de la Defensa del Trabajo (PROFEDET, 2020) establishes the key elements for identifying bullying and bullying behavior, as well as the legal avenues for action applicable in labor, criminal, administrative, and civil settings. It also includes mechanisms for institutional referral, case follow-up in administrative bodies, and provides legal guidance and support during mediation and conciliation processes, as well as legal representation of affected individuals, with the aim of guaranteeing the defense of their labor rights.

The practical guide for companies on violence and harassment at work, prepared by the International Labor Organization (ILO, 2022), provides the legal basis and responsibilities of employers in preventing workplace violence and harassment. Among the main actions recommended in this guide are ensuring and maintaining safe work systems and work environments free from safety and health risks, including those related to violence and harassment, as well as identifying the hazards and assessing the risks associated with these issues, and implementing appropriate measures to prevent and control them. Furthermore, the guide emphasizes the importance of providing clear information, ongoing training, adequate instruction, and constant supervision as key strategies to mitigate and avoid acts of violence or harassment in the workplace. Another protocol is the one for the prevention and response to cases of workplace violence of the Tribunal Electoral del Poder Judicial de la Federación (TEPJF, 2024), which aims to recognize and raise awareness for the prevention, response, and punishment of violence to achieve a violence-free work environment.

Also, the *Guía para la implementación del modelo de equidad de género* (Guide for the implementation of the gender equity model, Instituto Nacional de las Mujeres (INMUJERES, 2012) was identified. This guide aims to promote equal opportunities and treatment for women and men in the workplace, both for public and private organizations. This guide includes an organizational diagnosis with a gender perspective, which identifies gender gaps and inequalities within the organization; a gender equity policy, which establishes institutional commitments to promote equality and prevent discrimination; affirmative actions, which are specific measures to correct inequalities and foster equity; the formation of a gender equity committee; and training and awareness-raising, which includes staff training on gender and human rights issues. Finally, it integrates basic evaluation and continuous improvement tools to ensure its effectiveness and the make necessary adjustments. This guide highlights the importance of the participation of senior management and all staff in the implementation of the model, with the aim of promoting an organizational culture based on respect, equality, and non-discrimination.

As a result of the literature review, and from a social and labor justice perspective, the creation of safe work environments is essential for providing opportunities for women's inclusion in the workplace, both in public and private spaces.

3 Methodology

This research combines quantitative and qualitative methods and considers three main phases. The first one consists of a diagnosis of the situation to define the requirements of the proposed alert system, and how the proposal would be received by its users. In

the second phase, the monitoring device will be selected based on the identified technical specifications, and incident response protocols will be developed. Finally, the economic and social impact of the proposal will be assessed.

3.1 Diagnostics

In the first step of the methodology, data was collected using a Likert-scale questionnaire, ranging from 1 (strongly disagree) to 5 (strongly agree), which was administered to approximately 100 working-age women living in Mexico City. The sample size was determined non-probabilistically by convenience, considering factors such as participant availability and accessibility.

The objective of the questionnaire was to obtain relevant information on the participants' perceptions regarding the inclusion of women in the last-mile logistics sector. The results can be analyzed using Bronfenbrenner's (1994) ecological model as a structured framework. The microsystem of interest corresponds to the employee's direct interactions in the logistics chain within the workplace. Table 1 presents the level, the microsystemic factors, the identified problems, the way in which this proposal contributes to improvement, and the metric targets that can be employed.

Table 1. Microsystem of employee interactions in last-mile logistics

Level	Microsystemic factor	Identified problem	Proposed intervention	Target
Individual	Employee	Perception of insecurity	Self-defense workshops	70% female attendance
		Low confidence in technical skills	Mentoring with more experienced women	40% reduction in anxiety
			Skills certification	25% more women on complex routes
		Lack of device familiarity	Technical training for new users	100% of female users trained
Interpersonal	Supervisors	Workplace harassment	Standardized protocols	30% reduction in harassment reports
		Biased route assignment	Use of assignment algorithms with security criteria (SEMOVI data)	50% of safe routes and times assigned to women
			Visualization of equity metrics in route assignment	
	Coworkers	Sexist culture in distribution centers	Bi-monthly awareness workshops	80% male participation
	Clients	Harassment during deliveries	Panic button with real-time geolocation	30% reduction in customer harassment reports
			Bi-directional rating system	
			Geofence that alerts when approaching homes with a history of harassment	
	Family	Pressure due to dangerous hours	Notification system for trusted contacts	Support network for 100% of delivery women
Organizational	Company	Unsafe areas in the workplace	Improve lighting in distribution yards	Regulations and protocols reviewed every 2 years
		Outdated labor regulations	Implementation of a gender perspective in internal regulations, standardized protocols	
		Gender-blind policies		
Community	Mexico City Citizen contact	Unsafe infrastructure	Integration with SEMOVI data	100% integration
			Connection of the device network with C5 CDMX	

Table 1 identifies problems at the individual, interpersonal, organizational, and community levels, as well as practical proposals to address the identified problems. Significant improvements seem to can be achieved through the implementation of low-cost GPS devices for delivery workers, in conjunction with a safety protocol.

The use of these GPS geolocation systems was also addressed in the survey; the results are shown in Fig. 2. Most of the respondents (Fig. 2a, 85.4% in options 4 and 5) perceive insecurity as a determining factor in their choice of delivery jobs.

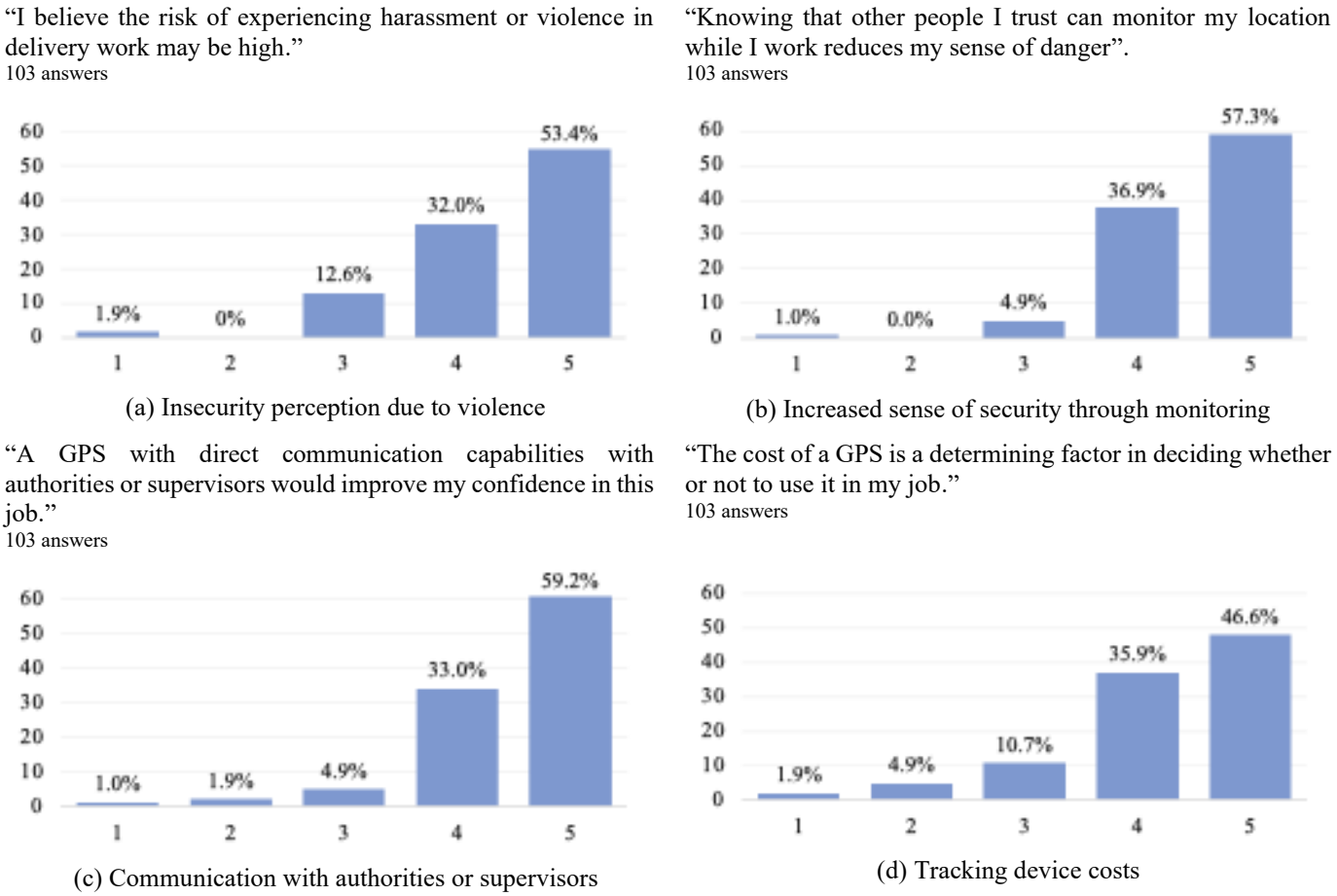

Fig. 2. Results of the survey used for diagnostics

Likewise, the ability to share one's location at any time with trusted individuals (Fig. 2b, 94.2% for options 4 and 5) and/or having a direct communication channel with authorities (Fig. 2c, 92.2% for options 4 and 5) are considered positive factors that would increase the perception of safety and support in risky work situations. For most respondents (Fig. 2d, 82.5% for options 4 and 5), the cost of the GPS is an important factor, suggesting a strong relationship between the price of the GPS and its acceptance and potential use in the delivery work environment. Furthermore, additional benefits, such as emergency alerts or real-time assistance, were found to add value to the GPS.

3.2 Selection of the tracking device

In the second phase, different monitoring device options were investigated that met the desired technical specifications and responded to the users' needs. To this end, the survey responses were considered, prioritizing key factors such as ease of use, reliability, and affordability. A prototype tracking device was evaluated from the perspective of implementation and operating costs, as well as system scalability.

To ensure the GPS device can be placed in inconspicuous locations, it must be compact and discreet, yet easily accessible in emergency situations. Furthermore, because the device must accompany the users throughout their workday, its battery must be capable of ensuring continuous operation throughout the entire workday. Another required feature is that the device must allow the user to be geolocated by trusted individuals, for example, through mobile devices such as tablets or cell phones. Field tests will help identify additional needs in the future, such as water resistance or an automatic alert algorithm based on the user's movement. It's also necessary to fine-tune the system to avoid excessive false alarms.

Among the main factors influencing the costs of satellite tracking services are the contract period; the different features offered by companies range from the most basic, such as real-time tracking, to more advanced ones such as vehicle speed monitoring, fuel efficiency, and personalized alerts. Another key factor is the frequency of vehicle location updates: the higher the frequency, the higher the cost. Monthly costs per vehicle associated with contracting a satellite tracking service can range from $10 to $30 USD for basic functions; when incorporating advanced services, these costs increase to $60 USD or more per vehicle per month. Additionally, initial installation and activation costs must be considered, which are not included in these estimates (ZeekGPS, 2024).

4 Technical proposal

4.1 Description of the selected device

Among the devices investigated and found suitable for this proposal are real-time mini GPS trackers, which are useful for both cars and motorcycles. Table 2 presents a comparison of 10 vehicle tracking and security device systems available on the Mexican market, considering the features included in their most basic packages. Features marked with "-" correspond to information not available in the consulted sources.

Tabla 2. Features of commercial tracking systems

Features	Devices									
	Angel Sense GPS	Bouncie	Car Lock	MOTO safety	OnStep GPS Tracking	Quartixs	Samsara	Spytec	TKStar	Viper Smart Start
Real-time tracking	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Geofence	✓	✓	-	✓	-	✓	✓	✓	✓	×
Speeding alert	×	✓	-	✓	×	✓	✓	-	✓	✓
Route history	✓	×	-	×	×	✓	✓	✓	✓	✓
Battery monitoring	×	×	✓	×	×	×	✓	×	×	×
Emergency button	✓	×	×	×	×	×	×	×	✓	✓
Vehicle diagnostics	✓	✓	✓	×	×	×	✓	×	×	✓
Remote vehicle locking	×	×	×	×	×	×	✓	×	×	×
Built-in Wi-Fi	×	×	×	×	×	×	×	×	×	×
Security alarm	×	×	×	×	×	×	×	×	✓	✓
Emergency assistance	×	×	×	×	×	×	-	×	×	×
Mobile app	-	-	✓	×	-	-	-	-	✓	-
Approximate device cost (USD)	$230	$90	$50	$70	Rental	Rental	$100-150	Free with subscription	$50 - $90	Activation cost
Monthly rental (USD)	$66	$10	$10	$25	$14	$15	$27	$23-35	$3	$12

* AngelSense (2025), Bouncie (2025), CarLock (2025), Motive (2025), MOTOsafety (2025), OneStep GPS (2025), Quartix (2025), Samara (2025), Spytec (2025), TKStar (2025), Viper (2025).

Some devices offer more comprehensive packages that include high-end functionalities, such as advanced connectivity, entertainment, semi-automated driving, and even business management for vehicle fleets. An example of a device that offers these – more expensive – options is Samara. Because many of the basic functions can currently be found on mobile devices, users perceive that the price of premium subscriptions is not justified (Redditor, 2024).

The GPS TKStar device has a compact size (9 cm high, 7.2 cm wide, and 2.2 cm deep), making it easy to carry and conceal, and it comes with a 5000mAh battery that provides up to 90 days in standby mode or 7 to 10 days of continuous use, ensuring reliable

performance throughout the workday. Its mobile tracking system includes software compatible with Android and iOS, supporting SMS and free web tracking, and operates through a SIM card on the GSM network without requiring a subscription, as long as sufficient balance is available. Accepting any 2G SIM card, it allows users to choose their preferred carrier, while advanced functions such as geofencing, overspeed alarms, route history for up to six months, and low-battery alerts enhance its monitoring capabilities. Priced between 50 and 90 USD with no mandatory monthly fees, the device only requires chip recharging with the carrier, starting at around 3 USD per month depending on usage and location. These specifications—compact design, long-lasting battery, compatibility with multiple carriers, and advanced monitoring features—make the TKStar GPS a cost-effective, flexible, and reliable solution for fleet management, vehicle protection, and personal tracking applications (TKStar, 2025).

The selected device, as well as its interface, is illustrated in Fig. 3a and b.

(a) GPS TKStar Device

(b) Mobile device's interface

Fig. 3. TKStar GPS device (a) and corresponding interface (b)

The GPS device described above provides key tools for always protecting and monitoring the user's location. Integration with a subscription-free app and compatibility with various mobile networks allow for accessible and an affordable communication. Similar devices, which however do not necessarily aimed at increasing the safety of women within the logistics chain, have been proposed by Caballero-Gil et al. (2018), Alcántara et al. (2023) and Swarnalatha et al. (2024).

4.2 Security protocol proposal

The analysis of the literature review on the programs and guidelines established by the SEMUJERES (2024), SEMOVI (2021), and the CELIG (2025), highlighted the importance of both public and private sectors implementing inclusive and equitable mobility and safety policies in Mexico City. These actions are essential to improve the conditions and safety of women involved in the last-mile workforce.

The use of geolocation technology is part of the priority strategies to mitigate risks on work commutes, as recommended by Barba (2023). This component aligns with the actions of the SEMOVI (2021) Walk Free, Walk Safe program, the CELIG (2025) gender-responsive mobility recommendations, and the safe work principles established by the STPS (2020).

The security protocol proposed for this work is the following:

a. Use of the GPS device for adaptive monitoring:

- **Basic mode**: Tracking every 15 minutes during daytime hours and in safe areas.
- **High-risk mode**: Tracking every 5 minutes during nighttime hours (starting at 6:00 PM) or in areas identified as dangerous based on data from the *Encuesta nacional sobre la dinámica de las relaciones en los hogares* (National survey on the dynamics of household relationships, ENDIREH), provided by the Instituto Nacional de Estadística y Geografía (INEGI, 2019), and the Secretaría de Movilidad de la Ciudad de México (SEMOVI, 2021).
- **Silent panic button**: Manual activation that sends real-time location to trusted contacts and local authorities linked to the CDMX app (Fig. 4).
- **Dynamic geofences:**
    - Creation of safe zones (distribution centers, purple dots, delegations) with automatic alerts if the user leaves these areas.

- Integration with SEMOVI (2021) data to update risk zones in real time.

b. Training and drills

These will be organized considering the recommendations of STPS (2020), SEMUJERES (2024), and ILO (2022), which establish a permanent training and capacity building program.

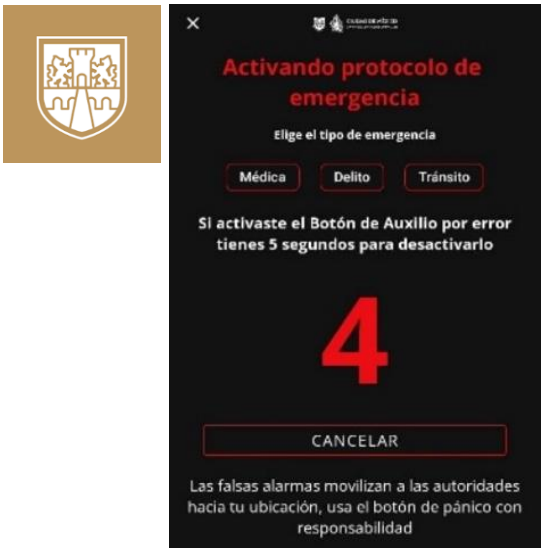

Fig. 4. Botón de auxilio de la appCDMX

- **Bimonthly workshops:**
  - Technical module: use of the GPS, how to interpret alerts and activate geofences.
  - Self-defense: collaboration with SEMUJERES for practical workshops against harassment (STPS, 2020).
- **Quarterly safety drills:**
  - Organization of drills in realistic scenarios, such as robbery or harassment to evaluate the response times in case of incidents. The target would be to have response times under 15 minutes.

c. Safe route design

Reflecting on Article 4, XII on gender equality, Article 6, IV on inclusive mobility planning, and Article 31, XIII, of the *Ley general para la igualdad entre hombres y mujeres* (General law for equality between men and women (Congreso de los Estados Unidos Mexicanos, 2006), which emphasizes safe inclusion strategies for women, Mexico City authorities are proposed to consider and issue recommendations to private companies in order to promote the inclusion of women in the logistics sector. The proposed considerations are:

- **Safe route design:**
  - Mapping of high-risk areas should be continuously updated by the authorities (ENDIREH, SEMOVI).
  - Routes with better lighting and proximity to safe havens, such as allied businesses, stations or union halls, should be preferred.
  - Assignment of routes to women should be based on perceived level of security.
- **Use of assignment algorithms:**
  - Prioritization of routes with:
    - Greater public lighting (SEMOVI data).
    - Proximity to safe havens (allied businesses).
  - Exclusion of areas with high rates of gender-based violence (ENDIREH, 2021).
- **Flexible hours:**
  - Assign preferentially daytime shifts for single mothers (IMCO, 2019).

d. Intervention and support

To ensure an effective intervention in any situation of theft or harassment, always prioritizing the protection of the people under surveillance, the following considerations are proposed:

- **The surveillance system should be operated by personnel trained in a gender perspective**
- **Use of tiered intervention protocols:**
    - Level 1: Contact the delivery person via phone call or SMS
    - Level 2: Alert nearby patrols (integration with the Mexico City Command, Control, Computing, Communications, and Citizen Contact Center, better known as C5 CDMX, appCDMX)
    - Level 3: Mobilization of community networks.

Fig. 5 presents a diagram representing the application of the proposed protocol for attention and response to risk events in last-mile delivery work activities.

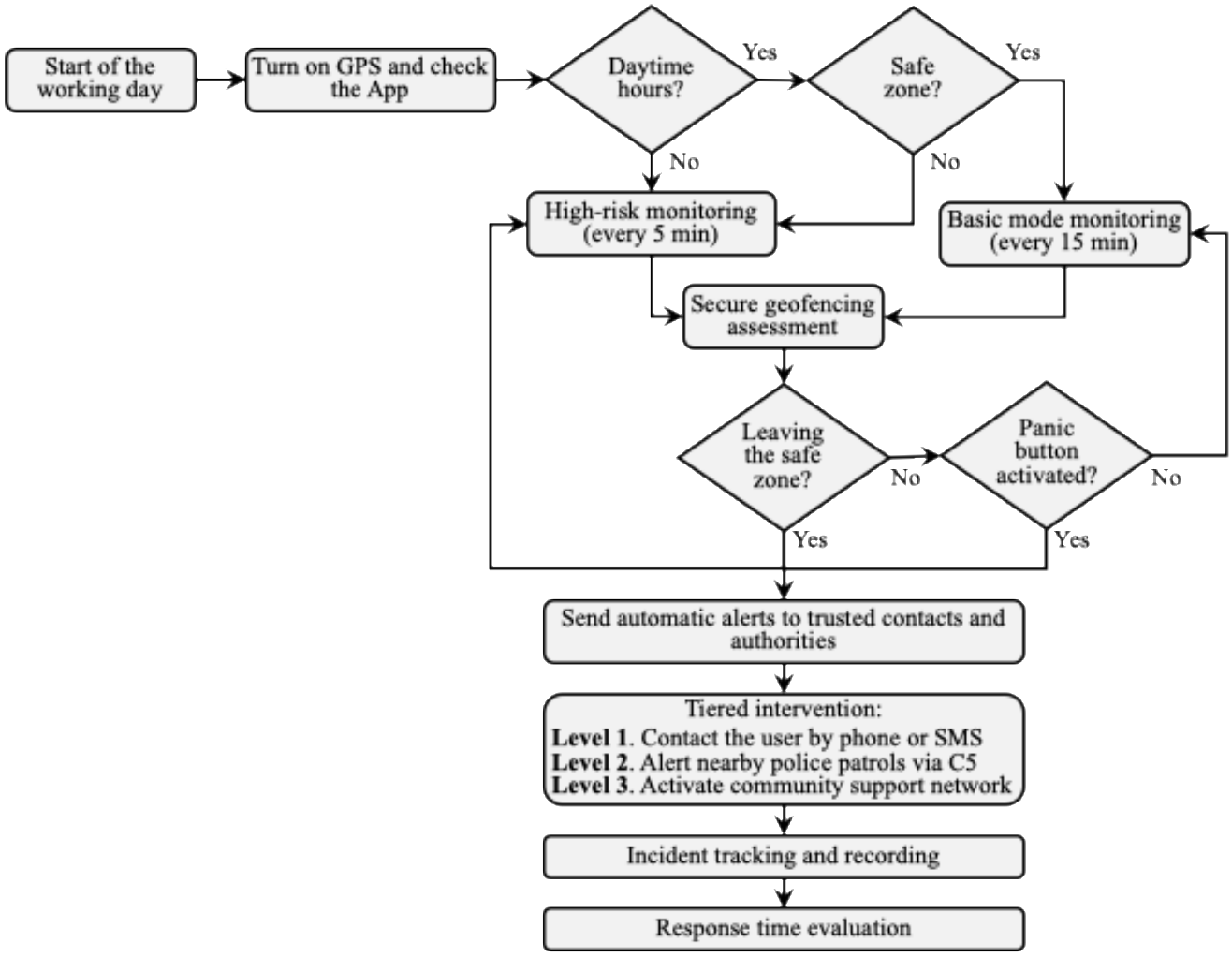

Fig. 5. Application of the protocol for handling risk events in last-mile delivery

Figure 5 illustrates the execution of the security protocol for female delivery workers in last-mile logistics in Mexico City, beginning with the activation of the GPS and verification of the app at the start of the shift. Depending on the area and time, an operating mode is established: basic or high-risk monitoring. The system constantly evaluates the location using geofences, and in the event of an eventuality, such as leaving a geofence or activating the panic button, an automatic alert is sent to trusted contacts and authorities. Based on this, a tiered intervention is deployed on three levels: contact with the user, alerting patrols through C5, and activation of community support networks. Finally, the incident is monitored, and the response time is evaluated.

5 Evaluation of the proposal

The implementation of a GPS-based system, along with a specific safety protocol for women working in the last mile, aims to improve their safety and job satisfaction, in order to increase female participation in logistics activities, especially in the so-called last mile. Table 2 describes the indicators for evaluating the impact and effectiveness of the presented proposal. The table considers several dimensions, including safety, economic, social, and operational impacts. To evaluate the success of the strategy, key indicators are established, such as the incident rate, return on investment, perception of safety, increase in the number of female delivery workers, and incident response time.

Table 2. Description and evaluation of proposed indicators

Dimension	Indicator	Metric	Data source	Frequence	Target
Segurity	Incident rate	$\frac{\#\text{ incidents}}{\#\text{ female delivery workers} * \text{month}}$	CDMX C5 records, surveys	Monthly	30% reduction per year
Economic	Return on investment	$\frac{\text{savings from incident reduction} - \text{GPS cost}}{\text{GPS cost} + \text{training costs}}$	Company financial records	Quarterly	Positive in 6 months
Social	Safety perception index	Average value in Likert scale (1-5)	Delivery surveys	Quarterly	Increase from 2.5 to 4.0 in 1 year
	Female attraction rate	$\frac{\#\text{ hired female delivery workers}}{\#\text{ total delivery workers}}$	Company employment records		15% increase in one year
	Female retention rate	$1 - \frac{\#\text{ delivery women who quit}}{\#\text{ female delivery workers}}$			
Operational	Average response time	Minutes from alert to response	GPS system records	Monthly	<15 minutes in 95% of cases

The economic benefit stems from increased operational safety. A safety protocol reduces the likelihood of risky situations, reducing costs associated with material losses or medical expenses. The social impact considers that improved safety conditions can encourage participation and encourage more women to consider last-mile work as a viable option, contributing to reducing the gender gap in the logistics sector (contributing to SDG 5, gender equality, and 10, reduction of inequalities). Furthermore, the implementation of tracking and location technologies, in conjunction with a safety protocol, generates a perception of protection for female workers, which positively impacts their satisfaction and job performance. A reduction in the average response time to an incident is also expected.

Potential disadvantages include the discomfort experienced by female delivery workers due to excessive employer surveillance, the fact that the responsibility for safety is transferred to the individual, and the technological dependence on GPS devices, which makes the proposal more feasible to implement in urban areas.

6 Results

The findings of this research are organized into three key dimensions: perception of security, technical feasibility of the selected GPS device, and potential impact on female labor inclusion.

6.1 Security perception and technological acceptance

The perception of personal security and the willingness to adopt new technologies are determining factors in the incorporation of women into traditionally male-dominated sectors, such as logistics and supply chain.

- 85.4% of those surveyed identified physical insecurity (robbery, harassment, or violence) as the main barrier to entering the sector. This figure makes it clear that the fear of suffering some type of aggression is a significant obstacle to women's inclusion in the workforce.

- 94.2% considered that real-time monitoring by trusted contacts would reduce their perception of danger. This data suggests that women consider digital support an effective mechanism in risky situations.
- 84.3% positively valued direct communication with authorities. This result reinforces the idea that women value having a timely response from authorities in the event of any eventuality. They also suggest that protective devices should incorporate this functionality as an essential element, as it increases the perception of security.
- 82.5% considered the cost of GPS as a determining factor, suggesting a strong relationship between the price of GPS and its potential use in the delivery work environment. This result indicates that the likelihood of implementing GPS technologies is determined by their affordability.

Additionally, it was found that additional benefits, such as emergency alerts or real-time assistance, would add value to GPS.

6.2 Evaluation of the GPS TKStar device

The device met the criteria of:

- Low cost,
- Continuous battery life,
- Geofencing, SMS alerts, and route history, and
- 2G network compatibility without subscriptions.

The results show that the perception of insecurity, one of the main barriers to female participation in last-mile logistics, is mitigated by accessible technological solutions, such as the TKStar GPS. The high acceptance of real-time monitoring and direct communication with authorities confirm that women value tools that provide a greater level of security. Furthermore, the combination of GPS technology with rapid response protocols increases women's confidence in joining the sector.

7 Conclusions

The implementation of GPS tracking technology seeks to generate greater opportunities for women who want to join the logistics sector. This is achieved by creating a safer work environment and reducing the perception of insecurity in this sector, and promotes female inclusion in a field traditionally dominated by men, thus contributing to greater gender equity. From an economic perspective, the integration of more women into the last-mile delivery sector strengthens workforce diversification and represents a significant source of income for female-headed households that depend on this activity, driving equitable economic growth. Creating a safer work environment for delivery workers can set a precedent for other sectors where female presence is restricted by security concerns, thus contributing to greater equity in access to job opportunities, greater social justice, and, consequently, a better state of well-being for the population at large.

References

Alba Vega, C., & Aparicio López, R. (2022). *Las mujeres repartidoras por plataformas digitales en la Ciudad de México durante la pandemia de la COVID-19*. En *Género en América Latina: homenaje a Barbara Potthast* (pp. 213–232).

Alba Vega, C., Bensusán, G., & Vega, G. (2024). *El trabajo del futuro con derechos laborales: Diagnóstico y estrategia de política pública para el reconocimiento de derechos laborales de las personas trabajadoras por plataformas digitales en la Ciudad de México*. Consejo Económico, Social y Ambiental de la Ciudad de México. https://ces.cdmx.gob.mx/storage/app/media/publicaciones2020/Estudio_derechos_laborales.pdf

Alcántara, A. D. T., Balbuena, R. B. H., Catapang, V. B., Catchillar, J. P. M., De Leon, R. E. P., Sanone, S. N. A., Juarizo, C. G., Sison, C. C., & García, E. A. (2023). *Internet of things-based smart helmet with accident identification and logistics monitoring for delivery riders*. In *Proceedings of the 10th International Electronic Conference on Sensors and Applications* (MDPI Proceedings, 58, Article 129). https://doi.org/10.3390/ecsa-10-16238

AngelSense. (2025). *AngelSense GPS tracker*. https://www.angelsense.com

Banco Mundial. (2020). *La participación laboral de la mujer en México*. Banco Mundial. https://documents1.worldbank.org/curated/en/753451607401938953/pdf/La-Participacion-Laboral-de-la-Mujer-en-Mexico.pdf

Barba, D. (2023). *Los protocolos de seguridad en el transporte*. LinkedIn. https://www.linkedin.com/pulse/los-protocolos-de-seguridad-en-el-transporte-david-barba/

Bouncie. (2025). *Bouncie GPS device*. https://bouncie.com

Boysen, N., Fedtke, S., & Schwerdfeger, S. (2021). *Last-mile delivery concepts: A survey from an operational research perspective*. *OR Spectrum, 43*(1), 1–58. https://doi.org/10.1007/s00291-020-00607-8

Bronfenbrenner, U. (1994). *Ecological models of human development*. In *International encyclopedia of education* (Vol. 3, pp. 37–43).

Caballero-Gil, P., Caballero-Gil, C., & Molina-Gil, J. (2018). *Ubiquitous system to monitor transport and logistics*. In *Proceedings of the International Conference on Performance Evaluation of Wireless Ad Hoc, Sensor, and Ubiquitous Networks* (pp. 71–75). ACM. https://doi.org/10.1145/3243046.3243049

CarLock. (2025). *CarLock – Advanced car tracking & alert system*. https://carlock.co

Carreño, A. (2018). *Cadena de suministro y logística*. Fondo Editorial de la PUCP.

Centro de Estudios Legislativos para la Igualdad de Género. (2025). *Análisis de los retos y pendientes que se enfrentan en la Ciudad de México en materia de igualdad de género y acceso a las mujeres a una vida libre de violencia en el marco de la nueva Ley General de Movilidad y Seguridad Vial*. Congreso de la Ciudad de México. https://genero.congresocdmx.gob.mx/wp-content/uploads/2025/01/Analisis-de-los-Retos-en-Materia-de-Movilidad-desde-la-Perspectiva-de-Genero.pdf

Congreso de los Estados Unidos Mexicanos. (2006). *Ley General para la Igualdad entre Mujeres y Hombres*. Diario Oficial de la Federación. https://www.diputados.gob.mx/LeyesBiblio/pdf/LGIMH.pdf

Cortez Oviedo, P. S., Ibañez Canelo, M. J., Brossi, L., & Castillo Hinojosa, A. M. (2023). *Resistencias sobre ruedas: Experiencias de mujeres y disidencias en apps de reparto*. *Revista Pensum, 9*(10), 61–78. https://doi.org/10.59047/2469.0724.v9.n10.40582

Cuberes, D., & Teignier, M. (2018). *Macroeconomic costs of gender gaps in a model with entrepreneurship and household production: The case of Mexico* (Policy Research Working Paper No. 136522). World Bank. https://documents1.worldbank.org/curated/en/754451556803462951/pdf/Macroeconomic-Costs-of-Gender-Gaps-in-a-Model-With-Entrepreneurship-and-Household-Production-the-Case-of-Mexico.pdf

Díaz, M., & Aparicio, R. (2024). *Mujeres trabajadoras en plataformas digitales: Ganarse la vida entre la precariedad y las desigualdades de género*. *Estudios Sociológicos de El Colegio de México, 42*, 1–20. https://doi.org/10.24201/es.2024v42.e2706

Fraszczyk, A., & Piip, J. (2019). *A review of transport organisations for female professionals and their impacts on the transport sector workforce*. *Research in Transportation Business & Management, 31*, 100379. https://doi.org/10.1016/j.rtbm.2019.100379

GetApp. (2025). *Quartix vehicle tracking: Pricing & features*. https://www.getapp.com/operations-management-software/a/quartix/pricing/

Gevaers, R., Van de Voorde, E., & Vanelslander, T. (2014). *Cost modelling and simulation of last mile characteristics in an innovative B2C supply chain environment with implications on urban areas and cities*. *Procedia – Social and Behavioral Sciences, 125*, 398–411. https://doi.org/10.1016/j.sbspro.2014.01.1483

Gonzalez, K., Kurshitashvili, N., Gonzalez Carvajal, K., & Pickup, L. (2023). *Closing gender gaps in transport*. World Bank. https://doi.org/10.1596/40850

Hopkins, D., & Akyelken, N. (2022). *MotherTruckers? The gendered work of freight and logistics*. En T. Wright, L. Budd, & S. Ison (Eds.), *Women, work and transport* (Transport and Sustainability, Vol. 16, pp. 71–86). Emerald Publishing Limited. https://doi.org/10.1108/S2044-994120220000016006

Instituto Mexicano para la Competitividad. (2019). *Trabajar sin dejar de vivir: Mejores prácticas de integración vida-trabajo en México*. https://imco.org.mx/wp-content/uploads/2019/11/2019_21_10_Trabajarsindejardevivir_Toolkit.pdf

Instituto Nacional de Estadística y Geografía. (2021). *Encuesta Nacional sobre la Dinámica de las Relaciones en los Hogares (ENDIREH) 2021: Presentación ejecutiva*. https://www.inegi.org.mx/contenidos/programas/endireh/2021/doc/endireh2021_presentacion_ejecutiva.pdf

Instituto Nacional de las Mujeres. (2012). *Guía para la implementación del modelo de equidad de género*. https://www.gob.mx/cms/uploads/attachment/file/27227/Guia-meg-2012.pdf

Lefebvre, H. (1968). *Le droit à la ville*. Anthropos.

Mahdawi, D., & Evans, J. (2022). *'Not like other women': Understanding the barriers for women in the transport sector and the role of trade unions*. En T. Wright, L. Budd, & S. Ison (Eds.), *Women, work and transport* (Transport and Sustainability, Vol. 16, pp. 339–355). Emerald Publishing Limited. https://doi.org/10.1108/S2044-994120220000016021

MOTOsafety. (2025). *MOTOsafety GPS tracker*. https://www.motosafety.com

Nigam, S. (2010). *Breaking the barriers: Women in logistics*. SSRN. https://doi.org/10.2139/ssrn.2428088

OneStep GPS. (2025). *OneStep GPS tracking*. https://www.onestepgps.com

Organización Internacional del Trabajo. (2022). *Guía práctica para las empresas sobre violencia y acoso en el trabajo*. https://www.ilo.org/sites/default/files/wcmsp5/groups/public/%40ed_dialogue/%40act_emp/documents/publication/wcms_862627.pdf

Pereira, R. H., Schwanen, T., & Banister, D. (2017). *Distributive justice and equity in transportation*. *Transport Reviews, 37*(2), 170–191. https://doi.org/10.1080/01441647.2016.1257660

Plambeck, E. L., & Ramdas, K. (2020). *Alleviating poverty by empowering women through business model innovation: Manufacturing & service operations management insights and opportunities*. *Manufacturing & Service Operations Management, 22*(1), 123–134. https://doi.org/10.1287/msom.2019.0844

Procuraduría Federal de la Defensa del Trabajo. (2020). *Protocolo para detectar, atender y acompañar a personas usuarias de la PROFEDET en casos de hostigamiento y acoso sexual y laboral*. https://www.profedet.gob.mx/Profedet/archivos/protocolos/Protocolo_Hostigamiento_y_Acoso_PROFEDET.pdf

Raj, R., Singh, A., Kumar, V., De, T., & Singh, S. (2023). *Assessing the e-commerce last-mile logistics' hidden risk hurdles*. *Discover Internet of Things, 3*, 100040. https://doi.org/10.1016/j.disa.2023.100040

Reddit user. (2024). *Does anyone actually subscribe to OnStar?* [Comment]. Reddit. https://www.reddit.com/r/chevycolorado/comments/1c6e72g

Reynolds, S. (2024). *Women in supply chain leadership: Barriers and opportunities* [Preprint]. Preprints. https://doi.org/10.20944/preprints202406.0499.v1

Rubery, J., Távora, I., Herman, E., Winton, A., & Castillo Larraín, A. (2024). *Women workers on the frontline and the Coronavirus pandemic*. En M. Rönnmar & S. Hayter (Eds.), *Making and breaking gender inequalities in work* (pp. 54–74). Edward Elgar Publishing. https://doi.org/10.4337/9781035337477.00013

Secretaría de las Mujeres de la Ciudad de México. (s. f.). *Programas*. https://semujeres.cdmx.gob.mx/programas

Secretaría de Movilidad de la Ciudad de México. (2021). *Programa integral de seguridad vial de la Ciudad de México (PISVI 2021–2024)*. https://www.semovi.cdmx.gob.mx/storage/app/media/PISVI-2021-2024_.pdf

Secretaría del Trabajo y Previsión Social. (2020). *Modelo de protocolo para prevenir, atender y erradicar la violencia laboral en los centros de trabajo*. https://www.gob.mx/cms/uploads/attachment/file/539287/Protocolo_Violencia_Laboral_0603-1amGMX__1_.pdf

Singh, S. (2024). *Bringing women back to work in the post-pandemic world*. *International Journal for Multidisciplinary Research, 6*(3). https://doi.org/10.36948/ijfmr.2024.v06i03.19082

Soja, E. W. (2010). *Seeking spatial justice*. University of Minnesota Press.

Spytec. (2025). *Spytec GPS tracker*. https://www.spytec.com

Subramanian, R. S., Nalini, M., Anish, T. P., Maheswari, B., Pajila, P. J. B., Girija, P., & Ezhilvendan, M. (2024). *Leveraging modern technology for gender equity and economic development*. En *Advances in human resources management and organizational development* (pp. 107–132). IGI Global. https://doi.org/10.4018/979-8-3693-3876-6.ch005

Swarnalatha, E., Donthoju, R., Rentapala, S., & Bhumika, P. (2024). *Microcontroller based women safety tracker device*. *International Journal of Innovative Science and Research Technology*, 530–534. https://doi.org/10.38124/ijisrt/ijisrt24apr851

Tech.co. (2025). *Samsara vs. Motive: Fleet management comparison*. https://tech.co/fleet-management/samsara-vs-motive

Tech.co. (2025). *Samsara vs. Motive: Fleet management comparison*. https://tech.co/fleet-management/samsara-vs-motive

TKStar. (2025). *GPS tracker TK905*. https://www.tk-star.com/product/TK905-4G.html

Tribunal Electoral del Poder Judicial de la Federación. (2024). *Protocolo para la prevención y actuación frente a casos de violencia laboral*. https://www.te.gob.mx/editorial_service/media/pdf/09042024140020284O.pdf

Unidad de Inteligencia del Mercado Laboral. (2023). *Personas trabajadoras de reparto en plataformas digitales: Contexto y desafíos* (Documento de trabajo No. 1). https://simel.mtps.gob.sv/wp-content/uploads/2024/01/Personas-trabajadoras-de-reparto-en-plataformas-digitales-Documento-de-Trabajo-N%C2%B0-1-2023.pdf

Viper. (2025). *Viper SmartStart*. https://www.viper.com/smartstart

Yang, B., Subramanian, N., & Al Harthy, S. (2024). *Are gender diversity issues a hidden problem in logistics and supply chain management? Building research themes through a systematic literature review*. *Journal of Purchasing and Supply Management, 30*(5), 100937. https://doi.org/10.1016/j.pursup.2024.100937

Yousuf, R., & Majid, Z. (2023). *Navigating the risks: A look at dangerous goods logistics management for women in logistics*. En N. A. Abdul Rahman & N. Mohd Nur (Eds.), *Women in aviation* (pp. 161–174). Springer. https://doi.org/10.1007/978-981-99-3098-2_12

ZeekGPS. (2024). *¿Cuánto cuesta un servicio de rastreo satelital en México?* https://zeekgps.com/cuanto-cuesta-un-servicio-de-rastreo-satelital-en-mexico/