COMBATING AGRICULTURAL AND FUEL THEFT VIA SOFTWARE SOLUTIONS: STANDARD AND AI-POWERED APPROACHES

Teodor LUPU[1], Adrian GÂNGA[1], Nicoleta MIHALACHE[1], Chiril BOTNARU[2], Monica RUSU[2]

e-mail: cocamonica.pfa@gmail.com

Abstract

Agricultural and fuel theft are persistent challenges faced by farms worldwide, resulting in financial losses and operational disruptions. However, software solutions, including standard software and AI-powered technologies, have proven to be practical tools in combating these thefts. Surveillance systems, access control systems, inventory management systems, and asset tracking systems are some of the standard software solutions that can be implemented on farms to prevent theft incidents. AI-powered solutions, such as machine learning algorithms and image recognition technology, can enhance the effectiveness of these solutions by analysing large amounts of data in real-time, providing predictive insights, and optimising farm operations. It is evident that software solutions play a crucial role in combating agricultural and fuel theft, and their adoption can significantly reduce the risks and losses associated with theft incidents. Farms need to assess their specific needs and requirements and choose the appropriate software solutions aligning with their operations and budgets.

Keywords: agricultural theft, machine learning, electronic identification (EID), crop monitoring

Agricultural theft is a significant and growing problem that affects farmers and growers worldwide. According to a UK National Farmers' Union report, agricultural theft cost farmers an estimated £50 million in 2020 (Smith K., 2020). Agricultural and fuel theft are significant challenges faced by farmers and the agriculture industry, resulting in significant economic losses and security concerns. However, software solutions, including standard software and AI-based technologies, have shown great potential to combat theft incidents and improve farm security.

In this article, we will explore how software solutions can be utilised to combat agricultural and fuel theft, focusing on both standard software and AI approaches. We will examine examples, data, and future suggestions for software development to address this critical issue effectively; we hope to encourage farmers and growers to adopt these tools and take proactive measures to protect their assets.

MATERIAL AND METHOD

While software solutions offer promising opportunities for combating agricultural theft, some challenges and considerations need to be considered. These include:

Cost - implementing software solutions for agricultural theft prevention may require an upfront investment in hardware, software, and infrastructure, as well as ongoing maintenance, updates, and support costs. Farmers need to carefully evaluate the costs and benefits of implementing such solutions and ensure that they are financially viable in the long run.

Integration - integration of software solutions into existing farm operations and systems may pose challenges. Farmers need to ensure that the software solutions they choose are compatible with their existing hardware, software, and data systems and can be seamlessly integrated into their workflow without disrupting their operations.

Connectivity - many agricultural areas may have limited or unreliable internet connectivity, which can affect the effectiveness of software solutions that rely on real-time data and remote monitoring. Farmers need to consider the availability and reliability of internet connectivity in their area and choose software solutions that can function offline or have offline data storage capabilities to ensure continuous operation.

Security - software solutions for agricultural theft prevention may involve collecting, storing, and analysing sensitive data, such as location data, surveillance footage, and access control information. Farmers need to prioritise the security and privacy of their data and choose software solutions that have robust security measures in place, such as encryption, authentication, and regular security updates.

[1] AXIOLOGIC SAAS, Iași, Romania
[2] Iasi University of Life Sciences, Romania

User-friendly interfaces - farmers and agricultural workers may have varying levels of technical expertise, and software solutions need to have user-friendly interfaces that are easy to use and understand. Training and support may be required to ensure that farmers and agricultural workers can effectively use the software solutions to combat agricultural theft.

RESULTS AND DISCUSSIONS

The use of software in combating agricultural theft has gained significant traction in recent years as farmers and law enforcement agencies seek more efficient and effective ways to prevent and detect theft incidents. One of the primary ways software can help prevent agricultural theft is through the use of geospatial technologies such as geographic information systems (GIS) and global positioning systems (GPS). By using these technologies, farmers can track and monitor the location and movement of their assets, such as equipment and livestock, in real-time, which can help them detect and respond to theft incidents more quickly. GIS can also be used to create maps and visualisations of farm assets, which can help farmers identify areas of vulnerability and prioritise security measures.

Moreover, the software can also help farmers and law enforcement agencies monitor and analyse social media and other online platforms for potential theft threats. For instance, some software tools use machine learning algorithms to analyse social media posts and online marketplaces for keywords and patterns related to agricultural theft, which can help detect and prevent theft incidents before they occur. Additionally, software tools can help farmers and law enforcement agencies share information and coordinate responses to theft incidents more effectively. For example, some platforms allow farmers to report theft incidents and share information with law enforcement agencies and other farmers in real-time, which can help increase the chances of recovering stolen assets and apprehending the perpetrators. Overall, the use of software in combating agricultural theft holds great promise in enhancing the security and resilience of the agricultural sector.

Another way that software can combat agricultural theft is by implementing electronic identification (EID) systems. EID involves using electronic tags or chips that can be attached to livestock (Cappai M.G. *et al.*, 2018) or other assets, allowing farmers to track and monitor them in real-time. EID systems can improve the overall management of livestock, as they can help farmers track the health and performance of individual animals and make informed decisions about breeding, feeding, and other aspects of animal care. EID systems can be integrated with other software tools, like data analytics platforms, to provide a more comprehensive view of farm operations and asset management. However, implementing EID systems requires careful consideration of ethical and legal issues, such as data privacy and ownership, animal welfare, and the potential impacts on small-scale farmers and traditional farming practices.

The use of software in combating agricultural theft offers several benefits and limitations. Geospatial technologies such as GIS and GPS allow farmers to track and monitor their assets in real-time, enabling quicker detection and response to theft incidents. Additionally, using GIS can help identify areas of vulnerability and prioritise security measures. However, implementing these technologies can become costly at a large scale, and they require technical expertise, making it difficult for small-scale farmers to afford to adopt them.

The use of software to monitor and analyse social media and other online platforms for potential theft threats can help detect and prevent theft incidents before they occur. This approach can also help law enforcement agencies coordinate responses and recover stolen assets. However, this solution is limited by the need for reliable internet connectivity and the potential for false positives in identifying theft threats.

Software solutions can be crucial in combating agricultural theft by providing tools and technologies that enhance security and enable farmers and agricultural businesses to manage and monitor their assets effectively. Here are some ways in which software solutions can help combat agricultural theft:

Software solutions can provide farmers with the ability to track and monitor their agricultural assets in real-time. This can include tracking the location and movement of crops, livestock, and farm equipment through GPS and other sensor technologies.

Asset tracking systems, such as GPS tracking, can be deployed on farm equipment and vehicles to provide real-time monitoring of their location, usage, and performance (Farooq M. *et al.*, 2019). These systems can help prevent theft incidents by triggering alerts whenever the unauthorised movement of equipment is detected. They can also provide insights into equipment usage patterns and behaviour, enabling farms to optimise their operations, reduce idle time, and improve fuel efficiency. A large farm in Brazil successfully implemented a GPS tracking system on their equipment and vehicles, which helped them prevent theft incidents and optimise equipment usage. The GPS tracking system provided real-time location

tracking of the farm's equipment and vehicles, along with detailed usage data such as fuel consumption, maintenance schedules, and operational efficiency. This allowed the farm management to monitor and manage their assets effectively, detect any unauthorised movement or usage, and take preventive actions.

Software solutions can enable farmers to remotely monitor their farms and agricultural assets using surveillance cameras, drones, and other remote sensing technologies.

Surveillance systems, including CCTV cameras, can be strategically placed across the farm premises to monitor activities and deter theft attempts. These systems can provide real-time monitoring, recording, and analysis of farm activities, enabling farm managers to detect and prevent theft incidents. For instance, a farm in the United States implemented a surveillance system that captured evidence of attempted theft incidents, leading to immediate action and deterring further theft attempts. The surveillance system was equipped with high-resolution cameras and video analytics software that could detect suspicious activities, such as trespassing or unauthorised entry into restricted areas. This allowed the farm management to respond promptly to potential theft incidents and prevent losses.

Software solutions can analyse data from various sources, such as weather patterns, historical theft data and sensor data, to generate insights and predictive algorithms that can help farmers identify patterns and trends associated with agricultural theft. For example, data analytics can help farmers identify high-risk areas or periods for theft, enabling them to take proactive measures to enhance security in those areas (Elijah O. *et al*., 2018).

Access control systems can be implemented at entry points, fuel storage tanks, and equipment sheds to restrict entry to only authorised personnel. This can include technologies such as biometric authentication, RFID (radio frequency identification) tags, and digital keys, which can help farmers ensure that only authorised personnel have access to their assets and detect any unauthorised attempts to gain access.

Geofencing can also be used to create virtual boundaries around fields and fuel storage tanks, triggering alerts whenever any unauthorised entry or movement is detected. A farm in Australia successfully implemented an access control system that prevented unauthorised access to fuel storage tanks and restricted entry to only authorised personnel. The system used biometric fingerprint authentication and RFID tagging to access equipment, ensuring that only designated personnel could access the fuel storage area.

Inventory management systems can utilise technologies such as RFID tagging to track and monitor the movement of livestock, crops, and other assets in real-time (Zhao J. *et al.*, 2010). These systems can also include automated record-keeping and analytics capabilities, enabling farm managers to optimise their operations. For example, a livestock farm in Canada implemented an inventory management system using RFID tagging, which allowed them to track and monitor the movement of animals, detect and prevent livestock theft incidents, and optimise livestock management. The system used RFID tags on animals and readers installed at various locations on the farm to track the movement of animals, record data such as weight and health status, and generate real-time alerts for any anomalies or suspicious activities.

Software solutions can generate automated reports and alerts based on predefined rules and thresholds. For example, farmers can set up alerts for unusual activities, such as the movement of assets during odd hours or in restricted areas, and receive notifications via email or mobile devices. This allows farmers to respond quickly to potential theft incidents and take appropriate action.

Agricultural theft and fuel consumption management are significant concerns for farmers worldwide. Theft of agricultural assets, such as crops, livestock, and equipment, can result in substantial financial losses and disrupt farm operations. AI-powered software solutions can provide valuable tools to combat agricultural theft effectively.

Predictive analytics powered by AI can also be crucial in fuel consumption management. Fuel consumption management is critical to efficient farm operations, as it directly impacts operational costs and environmental sustainability. For example, AI algorithms can predict optimal planting or harvesting times based on weather conditions to reduce fuel usage or recommend equipment maintenance schedules to ensure optimal performance and fuel efficiency.

AI-based technologies offer advanced capabilities for agricultural and fuel theft prevention. AI algorithms can analyse large volumes of data in real-time, detect patterns and make predictions to identify potential theft incidents.

One example of AI-based theft prevention is the use of remote monitoring and analytics in vineyards. By deploying sensors, drones, and other IoT devices in vineyards, farmers can collect real-time data on weather conditions, soil moisture, and other relevant factors (Javaid M. *et al*., 2023). This data can be analysed by AI algorithms that can detect anomalies and predict potential theft

incidents. For instance, if a sudden change in temperature or humidity is detected, it may indicate the presence of thieves trying to steal grapes from the vineyard. Early detection through AI-powered remote monitoring can enable prompt responses, reducing crop loss and improving farm security.

Similarly, AI-powered systems can be used to monitor the health and behaviour of livestock, which can provide insights into potential theft incidents. For example, wearable devices equipped with sensors can collect data on the heart rate, temperature, and location of livestock. AI algorithms can analyse this data and identify abnormal patterns, such as sudden changes in heart rate or prolonged periods of inactivity, which may indicate theft or distress. Farmers can receive real-time alerts and take immediate action to prevent theft or harm to their livestock.

Another application of AI in agricultural and fuel theft prevention is the use of predictive analytics. AI algorithms can identify patterns and predict potential theft hotspots and vulnerable areas by analysing historical data on theft incidents, weather patterns, farm operations, and other relevant factors. Farmers can proactively implement security measures, such as increased surveillance or improved access control in these identified areas, in order to prevent theft incidents.

One of the key applications of software solutions and AI in agricultural theft prevention is data analysis. These technologies can process and analyse large volumes of data from various sources, such as historical data on theft incidents, weather conditions, equipment movement, and other relevant parameters. AI algorithms can identify patterns and trends in the data that may indicate potential theft or misuse. For example, using AI-powered predictive analytics, unusual movement patterns of equipment or livestock, unexpected changes in crop growth patterns, or abnormal fuel consumption in specific locations could be identified.

Software solutions can generate early warning alerts, enabling farmers to take proactive measures to prevent theft. For instance, farmers can receive alerts when the AI algorithms detect suspicious activities, such as unauthorised access to fields, equipment movement during unusual hours, or unexpected changes in crop growth patterns. These alerts can trigger immediate action, such as increasing security measures, enhancing surveillance, or altering operational plans to prevent theft.

Video surveillance and image recognition technologies powered by AI can also be essential in agricultural theft prevention. These technologies can monitor critical areas, such as fields, storage areas, or equipment yards, for potential theft or unauthorised activities. AI algorithms can analyse video feeds or images in real-time and identify suspicious activities, such as trespassing, unauthorised access, or theft attempts. This can help farmers detect theft or unauthorised activities in real-time and take immediate action to prevent losses.

Moreover, NLP algorithms can be leveraged to gather information and insights related to potential theft activities. NLP can analyse data from various sources, such as weather reports, social media, and online forums, to identify relevant information and provide actionable intelligence to farmers or law enforcement agencies. For example, NLP can help identify chatter on social media related to theft incidents or suspicious activities in the vicinity of farms, allowing farmers to respond and take preventive measures proactively.

Furthermore, machine learning algorithms can play a crucial role in agricultural theft prevention by identifying anomalies in data related to theft incidents or other relevant parameters. By training on historical data, machine learning algorithms can learn to recognise normal behaviour patterns and detect deviations from the expected norm. For example, machine learning algorithms can identify abnormal movement patterns of equipment or livestock, unusual changes in crop growth patterns, or abnormal fuel consumption in specific locations and trigger alerts when deviations occur, allowing farmers to investigate and take action promptly.

AI-powered technologies, such as machine learning algorithms, can be integrated into software solutions to enhance their effectiveness in combating agricultural and fuel theft. These technologies can analyse large amounts of data in real-time, identify patterns and anomalies, and provide predictive insights for theft detection and prevention.

For example, a farm in South Africa implemented an AI-powered solution that used machine learning algorithms to analyze data from multiple sources, such as weather patterns, soil moisture levels, and livestock movement, to detect potential theft incidents. The system used predictive analytics to identify patterns of suspicious activities, such as unusual movement patterns or abnormal behaviour of livestock and triggered alerts for immediate action. This helped the farm management to detect and prevent theft incidents proactively, saving them significant losses.

Another example of AI-powered solutions is the use of image recognition technology for crop monitoring. With the help of drones or satellite imagery, AI algorithms can analyse images of crop

fields and identify potential theft or damage. For instance, a large farm in India implemented an AI-powered crop monitoring system that used satellite imagery and machine learning algorithms to detect crop health, growth patterns, and potential theft incidents. The system analysed the images in real-time, identified areas of concern, and alerted the farm management for prompt action. This enabled the farm to prevent crop theft and minimise losses.

In addition to theft prevention, AI-powered solutions can also optimise farm operations by providing insights and recommendations. For example, a farm in the United States implemented an AI-powered irrigation management system that analysed weather data, soil moisture levels, and crop growth patterns to optimise irrigation schedules. The system used machine learning algorithms to analyse the data and provided real-time recommendations for irrigation, resulting in efficient water usage and improved crop yield. This optimised farm operations and reduced the risk of theft incidents as the farm management could monitor and manage their crops effectively.

Furthermore, AI-powered remote monitoring and control systems can enable farmers to monitor fuel consumption and equipment performance remotely. These systems can provide real-time data on fuel levels, equipment utilisation, and operational parameters, allowing farmers to monitor fuel consumption in real-time and take immediate action if inefficiencies are detected. For example, farmers can remotely monitor equipment fuel levels, detect fuel theft attempts, or identify equipment malfunctioning that may result in excessive fuel consumption.

Blockchain technology can be used to create a tamper-proof ledger of all transactions related to fuel distribution and agricultural production. This can help prevent fraud and ensure transparency. Blockchain technology can play a significant role in combating agricultural and fuel theft by providing a secure and tamper-proof system for tracking and verifying transactions related to agricultural production and fuel distribution. Blockchain technology can be used to create a tamper-proof ledger of all transactions related to agricultural production and fuel distribution. This can help prevent fraud and ensure that all transactions are recorded accurately. Blockchain technology is decentralized, which means that there is no central authority controlling the system. This can help prevent fraud and ensure that all transactions are transparent and secure.

Machine learning algorithms can be used to analyze data from sensors and cameras. This can help identify patterns and anomalies that may indicate theft. Machine learning algorithms can play an important role in combating agricultural and fuel theft by analyzing data from various sources such as sensors, cameras, and transaction records.

Machine learning algorithms can be used to detect fraud in transaction records related to agricultural production and fuel distribution. For example, machine learning algorithms can analyze transaction records to detect patterns of suspicious activity, such as transactions that occur at unusual times or involve unusually large amounts of fuel.

Machine learning algorithms can be used to monitor agricultural production and fuel distribution in real-time. For example, machine learning algorithms can analyze data from cameras to detect any suspicious activity at fuel depots or storage facilities.

Machine learning algorithms can be used to assess the risk of agricultural and fuel theft in different locations. For example, machine learning algorithms can analyze data on past theft incidents to identify areas that are at high risk for theft.

Standard software solutions can provide effective tools for agricultural and fuel theft prevention. These solutions include farm management software, security camera systems, access control systems, and alarm systems.

Farm management software can give farmers real-time visibility and control over their farm operations. These software solutions typically include features such as inventory management, crop monitoring, livestock tracking, and equipment management. By implementing farm management software, farmers can keep track of their assets, monitor operations, and detect anomalies that may indicate potential theft incidents. For example, if a farmer notices discrepancies between actual crop yields and recorded yields in the farm management software, it may signal possible crop theft.

Security camera systems can also be employed to monitor farm premises and deter theft incidents. Surveillance cameras can be strategically placed in key areas, such as entry points, storage areas, and livestock enclosures, to capture video footage that can be reviewed in case of theft incidents. Access control systems, such as key cards or biometric authentication, can restrict access to farm facilities and equipment, preventing unauthorised individuals from gaining entry.

Alarm systems can provide real-time alerts in the event of theft incidents. These systems can include motion sensors, door sensors, and vibration sensors that can detect unauthorised access or tampering. When triggered, the alarm systems can send alerts to farmers or designated personnel, enabling swift responses to prevent theft or apprehend thieves.

In addition to combating agricultural theft and monitoring fuel consumption, software solutions and AI have numerous other applications in agriculture. Some of the key areas where these technologies are being utilised include:

Crop management - AI-powered software solutions can analyse data on weather conditions, soil moisture, crop growth patterns, and other relevant parameters to provide farmers with recommendations on optimal planting times, irrigation schedules, fertilisation strategies, and pest management practices (Javaid M. *et al*., 2023). This can help farmers optimise crop production, reduce input costs, and minimise environmental impact.

Disease and pest detection - AI algorithms can analyse data from sensors, satellite imagery, and other sources to detect early signs of disease or pest infestation in crops. Early detection can help farmers take timely action to prevent the spread of diseases or pests and minimise crop losses.

Harvesting optimisation - AI-powered software solutions can analyse data on crop maturity levels, weather conditions, and equipment availability to optimise harvesting schedules and minimise losses due to over-ripening or adverse weather conditions.

Livestock management - AI can be used to monitor the health and behaviour of livestock and analyse data on feed intake, movement patterns, and other parameters to detect signs of stress, illness, or abnormal behaviour. This can help farmers take proactive measures to ensure the well-being of their livestock and optimise their production.

Soil management - AI algorithms can analyse soil data, such as nutrient levels, pH levels, and moisture content, to provide farmers with recommendations on optimal soil management practices, including fertilisation, liming, and irrigation. This can help farmers optimise soil health, crop growth, and yield.

Supply chain optimisation - AI can optimise the entire agricultural supply chain, from production to distribution. For example, AI-powered software solutions can analyse data on transportation routes, inventory levels, demand patterns, and market prices to optimise transportation logistics, reduce wastage, and ensure timely product delivery to markets.

Resource conservation - AI can play a vital role in managing scarce resources in agriculture, such as water and energy. AI algorithms can analyse data on weather conditions, soil moisture, crop water requirements, and irrigation systems to optimise water usage and minimise waste. Similarly, AI can optimise energy usage in agriculture by analysing data on equipment performance, operational parameters, and renewable energy sources to reduce carbon footprint and operational costs.

Market analysis and prediction - AI-powered software solutions can analyse data on market trends, consumer preferences, and pricing patterns to provide farmers with market insights and predictions. This can help farmers make informed decisions about what crops to grow, when to sell and at what price, maximising their profits and reducing market risks.

Several real-world examples showcase the effectiveness of software solutions, including standard software and AI technologies, in combating agricultural and fuel theft.

Case Study 1: GPS Tracking and Remote Monitoring in Agriculture

A farm in the Midwest United States implemented a GPS tracking and remote monitoring system for their farm equipment, including tractors, harvesters and other machinery. The GPS tracking system allowed the farm to monitor the real-time location of their equipment and receive alerts in case of unauthorised movement or theft. The remote monitoring system included surveillance cameras and motion sensors strategically placed across the farm, providing visibility and security to different farm areas. The system helped the farm reduce theft incidents, recover stolen equipment, and improve overall farm security.

Case Study 2: AI-powered Livestock Monitoring

A livestock farm in Australia implemented an AI-powered livestock monitoring system to prevent theft and improve the health and welfare of their animals. The system included wearable devices equipped with sensors that collected data on the livestock's heart rate, temperature, and location. AI algorithms analysed the data in real-time and provided alerts to the farm manager in case of abnormal patterns, such as prolonged periods of inactivity or sudden changes in heart rate. The system enabled the farm to detect and prevent theft incidents quickly, as well as monitor the health and well-being of their livestock.

As technology continues to evolve, several future software development suggestions can further enhance software solutions' effectiveness in combating agricultural and fuel theft.

Integration of Multiple Technologies - combining different technologies, such as GPS tracking, remote sensing, IoT devices, and AI analytics, can provide a more comprehensive and robust solution for theft prevention. For example, integrating GPS tracking with remote sensing data can provide real-time information on the location of

farm assets and environmental conditions, allowing for better detection of theft incidents.

Predictive Analytics and Machine Learning - further advancement in predictive analytics and machine learning can enable more accurate and timely predictions of potential theft incidents. By analysing a larger dataset and incorporating more variables, AI algorithms can better identify patterns and trends that may indicate theft, allowing for proactive measures to prevent theft incidents.

Enhanced User Interfaces and Mobile Applications - user-friendly interfaces and mobile applications can improve the usability and accessibility of software solutions for farmers. Farmers should be able to easily monitor their farm operations, receive real-time alerts, and take necessary actions through intuitive and user-friendly interfaces. Mobile applications can provide on-the-go access to farm data and alerts, allowing farmers to manage their farm security even when they are not physically present on the farm.

Cloud-based Solutions - cloud-based solutions can provide scalability, flexibility, and ease of implementation for farms of all sizes. Cloud-based platforms can securely store and analyse large volumes of farm data, enabling real-time monitoring and analysis. Additionally, cloud-based solutions can allow for remote access and management, making it convenient for farmers to monitor and manage their farm security from anywhere, anytime.

CONCLUSIONS

Agricultural and fuel theft is a critical issue faced by the agriculture industry, resulting in significant economic losses and security risks for farmers. However, software solutions, including standard software and AI technologies, have shown great potential to combat agricultural and fuel theft. GPS tracking, remote sensing, IoT devices, and AI analytics can provide real-time monitoring, early detection of theft incidents, and predictive analytics to prevent theft. Examples of successful implementations, such as GPS tracking and remote monitoring in agriculture and AI-powered livestock monitoring, have demonstrated the effectiveness of these technologies in improving farm security.

To further enhance the effectiveness of software solutions in theft prevention, future developments could include integrating multiple technologies, such as GPS tracking with remote sensing and IoT devices, to provide a more comprehensive solution. Advancements in predictive analytics and machine learning can enable more accurate and timely predictions of theft incidents, while enhanced user interfaces and mobile applications can improve usability and accessibility for farmers. Cloud-based solutions can provide scalability and flexibility, allowing for remote access and management of farm security.

In conclusion, software solutions, including standard software and AI technologies, have the potential to improve theft prevention significantly in the agriculture industry. By leveraging real-time monitoring, early detection, predictive analytics, and user-friendly interfaces, farmers can proactively prevent theft incidents, reduce losses, and enhance overall farm security. As technology continues to evolve, further advancements in these areas can further strengthen the effectiveness of software solutions in combating agricultural and fuel theft. Farmers, technology providers, and policymakers must collaborate and harness the power of software solutions to address this critical issue and protect the livelihood of farmers.

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