Chapter 7

Standardization in Elevator Systems: Call and Display Panel Design Compatible with CANopen Communication Protocol

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Abstract

Since each of the elevator motherboards produced in Turkey today uses its own special communication protocol, the panels must be adapted separately to each system, and this leads to serious time and cost loss in the production process. For this purpose, this study aims to ensure that elevator control cards developed by different manufacturers work in harmony with common call and display panels. In this context, a call and display panel compatible with the CANopen Lift (CIA-417) profile, one of the international standards, has been designed. The embedded software infrastructure was created with the CANopenNode open-source library and the system's error analysis was performed with the CAN Analyzer. In addition, the sustainability and usability of the system was increased with the architecture that allows software updates and parameter changes to be made remotely. The prototype developed at the end of the project was tested in pilot elevators and successful results were obtained. With this study, a domestic solution that will reduce Turkey's dependence on imports has been presented. In addition, the way will be paved for CIA-417 compatible panel production.

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INTRODUCTION

Today, elevators have become an indispensable and frequently used tool in people's lives. The increase in urbanization, verticalization in building designs, and the increase in the number of elderly people have made the use of elevators an inevitable necessity in both residential and commercial buildings (Ming et al., 2018). Modern elevator systems not only serve as a transportation function, but also include many factors such as energy efficiency, user safety, and interactive interface solutions as an integral part of smart building infrastructures. At this point, call and display panels, which are an important component of elevator systems, are the basic units that provide real-time data exchange between the user and the system (Al-Kodmany, 2023a).

Due to reasons such as increasing user density, high number of floors, and need for solutions for emergency situations, it has become important for these panels to be faster, safer, adaptable and have a standard structure (Al-Kodmany, 2023b). Ergonomic approaches in elevator design are extremely important in terms of increasing comfort, reducing physical strain and ensuring ease of use for users of all ages and abilities (Perrucci et al., 2025). In this context, with the spread of IoT-supported smart systems, especially within the framework of building automation systems and Industry 4.0, elevators are expected to be able to communicate with other building components, integrate with central management systems and be monitored remotely (Van et al., 2020). Despite these developments, there is a major lack of standardization among call and display panels used today. This lack is due to incompatibilities between control cards and panel systems from different manufacturers, which results in increased costs, longer integration times and update difficulties.

The fact that control cards (motherboards) from different manufacturers use their own special communication protocols requires that call and display panels in elevator systems be customized for each manufacturer. This complicates the production process and causes serious time and cost losses in maintenance and compatibility processes. In particular, due to different communication protocols, special software and hardware adaptations must be made so that the panels can work integrated with each control card. It is stated that this situation limits the scalability and modularity of the systems. (Pöttner et al., 2012). In addition, most of the existing panels do not have the infrastructure to meet modern industrial needs such as remote software update, parameter change or fault diagnosis. This deficiency reduces the flexibility of the systems and prevents rapid response to the changing needs of the users. In this context, the development of universal panel systems based on a common protocol has become a great necessity. Standards such as CANopen and specifically CAN in Automation (CiA)-417 (CiA, 2025) have been developed to solve this problem, allowing devices from different manufacturers to work together on the same communication network. Such standardization facilitates integration between devices and increases system reliability by reducing maintenance costs (Arleklint, 2019).

The CANopen protocol, which is widely used in industrial automation systems, enables many devices to communicate over the same line with its flexible and modular structure. CANopen is an open and standard communication protocol that allows devices from different manufacturers to work together. This protocol supports real-time data exchange between devices and facilitates system configuration (Embien, 2025). The CiA-417 profile, a version of the CANopen protocol specifically developed for elevator systems, is defined to provide compatible and secure communication between call and display panels and control systems. CiA-417 specifies communication interfaces for virtual devices used in elevator systems. This allows components such as call buttons, cabin displays, and door control units to communicate over a standard protocol. The CiA-417 profile provides detailed object dictionaries for both data exchange and parameter management, enabling the development of systems that comply with the plug-and-play principle. This allows devices from different manufacturers to work seamlessly on the same communication network, thus facilitating system integration (CiA, 2025).

In recent years, various researches have been carried out on the use of CANopen and CiA-417 protocols in elevator systems. Sußmann and Meroth (2017) detailed the model-based development processes of elevator components that comply with the CiA-417 standard. This study demonstrated how the integration processes of elevator systems can be optimized using Matlab/Simulink-based modeling and Hardware-in-the-Loop (HIL) test methods. It was also stated that systems developed using the CANopen protocol allow components from different manufacturers to work seamlessly on the same communication network. Such studies reveal the potential of CANopen and CiA-417 protocols in terms of integration and performance improvements in elevator systems. Pöttner et al. (2012) evaluated the use of Bundle Protocol (BP) in Delay Tolerant Wireless Sensor Networks (DT-WSN) and demonstrated the practical effectiveness of this protocol with the "Data Elevator" application, where they used the physical movement of the elevator as a carrier in data transmission. In the study, a communication infrastructure that is both compliant with standards and flexible was established by using BP over IEEE 802.15.4 based communication with low-power sensor nodes. In addition, it was shown that the communication load on embedded systems can be minimized and full data delivery can be provided even in delayed data transfer with the modular BP implementation called μ-Delay Tolerant Networking (μDTN). This approach is an important example to overcome similar difficulties in the process of integrating industrial protocols such as CANopen into elevator systems. A different study on the verification of real-time communication and the development of test systems compatible with the CANopen protocol was done by Sußmann and Meroth (2017). An FPGA based real-time simulation of an absolute encoder conforming to the CANopen CiA 406 standard has been performed, and a model that can be directly embedded into hardware has been developed with HDL Coder using the Simulink-RTL flow. The simulator is configured to support both cyclic broadcasting of TPDO1 messages and timer-based protocol mechanisms such as heartbeat. Thus, the CANopen-based communication of the elevator controller has been tested without the need for physical hardware. In this respect, the study shows that CANopen communication tests can be modeled in a reusable, modular and platform-independent manner.

This study aims to develop a CIA-417 compatible call and display panel, which does not yet have a domestic example in Turkey. The developed system has gone through many technical stages such as embedded software infrastructure integrated with the CANopenNode open-source library, CAN Analyzer supported communication tests, remote software update capability and pilot field tests. In this respect, the study offers a low-cost, sustainable and integrable solution for both manufacturers and users. It also aims to reduce import dependency by encouraging domestic production.

MATERIAL AND METHODS

In this study, indicator-call panels were designed and developed by considering parameters such as floor, direction, door and special indicators suitable for CiA-417 profile. Within the scope of the project process, firstly membership to CiA community was provided and necessary technical documents were obtained. Then, a CiA-417 compatible motherboard and test panels were supplied and test software such as CAN Analyzer and CANopen Magic Professional were used to analyze the communication infrastructure.

In the hardware design process for the panel prototype, printed circuit board (PCB) schematic and layout studies were carried out, and then

PCB production and supply services were provided as outsourced. In the embedded software development phase, core software compatible with the microcontroller (MCU) was developed based on the open source CANopenNode Library. In this context, object dictionaries for CiA-301 and CiA-417-1/2/3/4 profiles were created, TPDO (Transmit Process Data Object) and RPDO (Receive Process Data Object) packages were defined and communication tests were successfully performed.

In the developed system; basic components such as microcontroller, step-down converter module, LED dot matrix module, button I/O connection and CAN communication unit were used. The hardware components preferred in the study and the methods followed are presented in detail below.

Material

As a microcontroller, NUVOTON's ARM Cortex-M0 family was preferred due to its integrated CAN peripheral unit, low cost and sufficient performance. For visual display purposes, a 10x15 matrix consisting of LEDs was configured on the PCB. Darlington transistors were used for switching this matrix, and shift registers were used for connecting it to the microcontroller. Transistor switching circuits were designed to detect button inputs and drive call acceptance LED outputs. For CAN Bus communication, the SN65HVD1050 integrated circuit, manufactured by Texas Instruments and optimized for electromagnetic interference (EMC), which is widely used in the industry, was preferred. CAN analyzer was used for CAN line communication control and analysis, and PCAN Analyzer, manufactured by PEAK System, which has international support, was preferred. CANopen Magic software, manufactured by PEAK System, was used to display CANopen structures (NMT (Network Management), Error, Heartbeat, Service Data Object (SDO), Process Data Object (PDO)) on the computer. The hardware architecture and CANopen communication structure of the developed system are presented schematically in Figure 1.

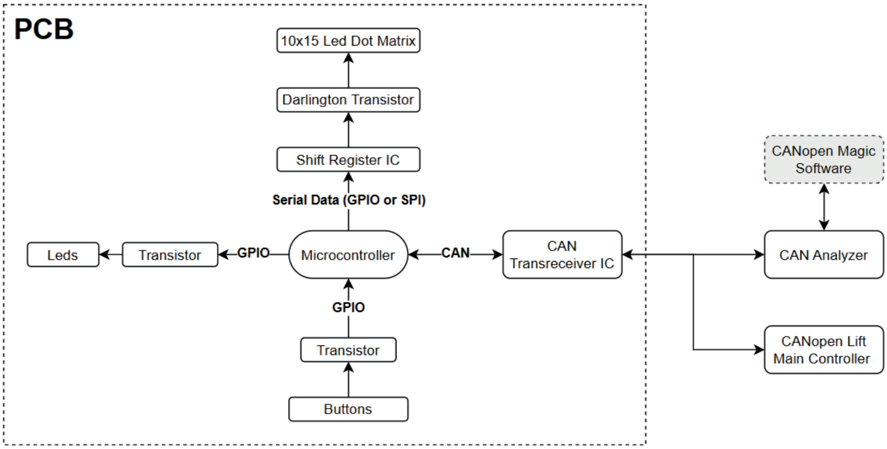

Figure 1. Microcontroller-based hardware architecture and CANopen communication structure for the developed elevator floor button panel.

Software Architecture

In the hardware-based software development process, Keil uVision, a free development environment offered by NUVOTON for the ARM Cortex-M family, was used. The system software consists of three main modules: display control, peripheral management, and CANopenNode optimization. The display control module was designed using the GPIO and TIMER peripherals of the microcontroller. The LED positions were controlled via the GPIO unit, while the matrix timing was managed with the TIMER unit. Peripheral management was implemented using the Board Support Package (BSP) library provided by NUVOTON. The CANopenNode middleware was provided as open source via GitHub and was made compatible with the peripherals of the NUVOTON microcontroller and used in the system.

CANopen Protocol

CANopen is a high-level communication protocol developed by the CiA organization and operates on the CAN bus infrastructure. When the fundamental differences between CANbus and CANopen are examined, it is seen that CANopen offers advantages such as advanced error monitoring, flexible structure, network management and real-time communication. In this context, in industrial applications requiring complex and reliable communication, it would be more appropriate to prefer CANopen over the basic CANbus protocol. A comparison of CANbus and CANopen protocols in terms of various technical features is summarized in Table 1.

Table 1. Comparison of CANbus and CANopen protocols in terms of technical features

Feature	CANbus	CANopen
Definition	Low-level message-based communication protocol.	A high-level communication protocol built on CANbus that enables standardized communication between devices.
Layer	It consists of 2 layers: • Data Link Layer • Physical Layer	It consists of 7 layers: • Application Layer • Presentation Layer • Session Layer • Transport Layer • Network Layer • Data Link Layer • Physical Layer
Standardization	ISO 11898	EN 50325-4 (Developed by CiA)
Scope of Communication	Provides prioritized, unstructured data transmission based on message identifiers.	Provides structured communication covering device configuration, state management, and real-time data transmission.
Contact Method	Data transmission is performed based on Message Identifier.	Function-based communication is achieved using Node ID and COB-ID (Communication Object Identifier).
Application Layer Support	Not defined.	Provides a comprehensive structure at the application layer, including device profiles, object dictionary, and communication services.
Data Structure	Basic CAN data frames with a fixed structure (ID, control bits, data field, CRC).	Includes configurations such as Object Dictionary, SDO and PDO.
Real Time Communication	Limited; enables fast communication based on message priorities.	Provides deterministic and synchronized real-time data transmission via PDO and SYNC messages.
Device Configuration	Not supported; configuration is not possible at the protocol level.	Device configuration and parameter settings can be performed via SDO services.
Network Management	None.	Device state management is provided through the NMT mechanism (Operational, Pre-operational, Stopped).
Error Tracking and Management	Basic error control is performed (bit error, CRC, frame error).	Device health and connection status are continuously monitored through Heartbeat and Node Guarding mechanisms.

Manufacturer Independent Compatibility	Not provided; requires custom integration for device-to-device communication.	Thanks to standard device profiles (e.g., CiA 401, CiA 417), devices from different manufacturers can operate compatibly.
Typical Application Areas	Automotive ECU communication, in-vehicle control units, embedded systems.	Industrial automation (PLCs, HMIs, drives), medical devices, elevator control systems, robotic applications.

CANopenNode Integration Control

After the integration of the CANopenNode library and the BSP (Board Support Package) library of the microcontroller is completed, a test process is applied to verify whether the CANopenNode is working properly. During this verification process, the PCB is connected to the computer via a CAN analyzer and is put into operation by applying power. CANopen Magic software is started on the computer and the network management interface is accessed via the "View >> Network Management" menu. In this interface, the "All Nodes" option is activated and the status of all nodes in the network can be monitored. Then, one of the "Operational", "Preoperational" and "Stopped" states defined in the CANopen protocol is selected and the relevant command is sent. In response to this command, a response message is expected to be sent by the PCB.

During this process, the transmitted and received messages are monitored using the Trace window. The monitoring screen of the CANopen messages received during the test process is shown in Figure 2. As shown in Figure 2, if the expected response message is detected successfully, it is verified that the integration of the CANopenNode library with the BSP library is performed correctly.

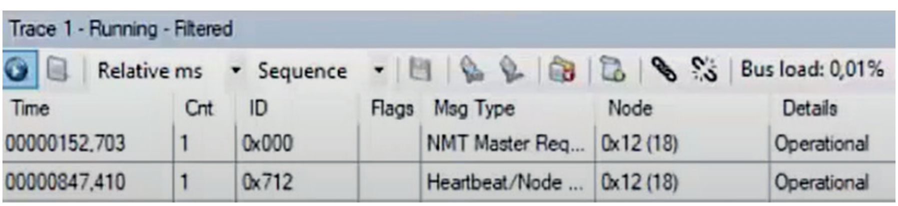

Figure 2. Monitoring of "NMT Master Request" and "Heartbeat" messages from the PCB after CANopenNode integration using a CAN analyzer software (The figure is taken from the trial version of CANopen Magic Professional software).

Usage of CANopenEditor

After verifying the integration of the CANopenNode library with the microcontroller, the object dictionary must be created in order for the system to fully provide its functionality. The object dictionary is the basic structure that defines the parameters to be used during device operation and plays a critical role in managing data exchange within the CANopen protocol.

The parameters defined in the object dictionary are divided into three main categories according to the index values they receive: communication-specific parameters, manufacturer-specific parameters, and device profile parameters. This classification is made to standardize data organization and ensure interoperability between devices.

In this study, CANopenEditor software, which was developed in accordance with CANopenNode library, is used. The related application can be accessed from https://github.com/CANopenNode/CANopenEditor/releases. The user interface for the process of defining a new object word is shown in Figure 3. Also, as an example, the process of adding a new object word under the heading "Manufacturer Specific Parameters" is explained below:

1. The CANopenEditor application is started and a new project is created using the File >> New menu.
2. To save the created project, follow the "File >> Save Project" path. The location where the project will be saved is the folder containing the "CO_App" and "CO_Driver" directories, outside the CANopenNode protocol stack.
3. In order to add the basic communication parameters to the object dictionary, go to the "Insert Profile >> DS301_profile.xpd" extension from the tabs and add the parameters of the DS301 profile with the "Insert" command in the opened window.
4. Then, go to the "Object Dictionary" tab and define a new object word with the "Add" option under the "Index" heading.
5. As shown in Figure 3, the creation process is completed by entering the index value, name and object type information for the relevant object (Create).

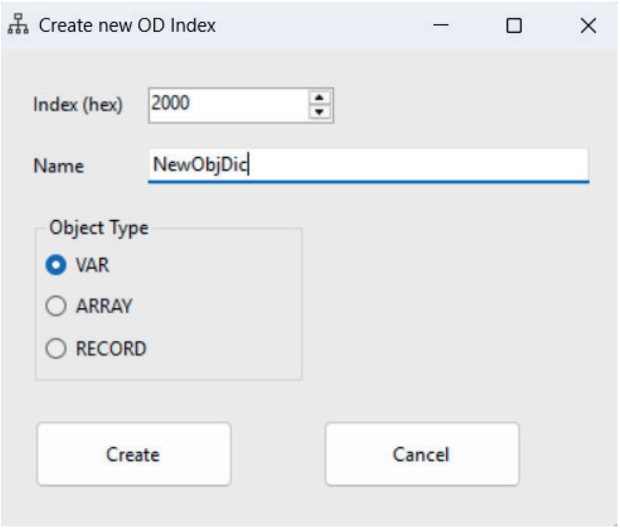

Figure 3. Screen for creating a new Object Dictionary entry in the CANopenEditor interface

As a result of these operations, the object dictionary structure that complies with the CANopen protocol is created and the device's communication, manufacturer-specific and profile-based parameters are systematically defined. In the process of configuring the properties of the created object dictionary index, the data type, SDO access permissions and PDO mapping settings must be defined. This step directly affects the functionality of the device by determining the object access format, data type and its relationship with communication protocols. For example, let's define the data type for the created object word as unsigned32, SDO access as free and TPDO. The settings that need to be made in this case are shown in Figure 4.

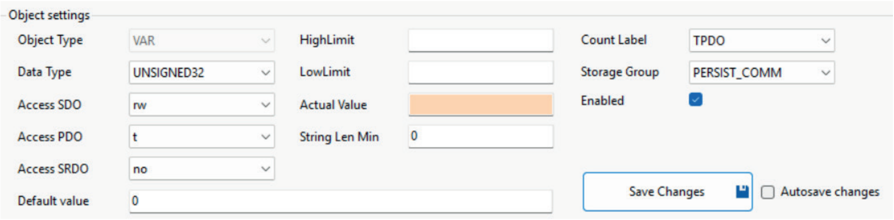

Figure 4. Configuration of data type, access rights, and PDO mapping settings for an object dictionary index in the CANopenEditor interface.

When you switch to the “TX PDO Mapping” tab, it is expected that the previously created object word will be displayed in the “Available Objects for PDO” section. At this stage, one of the default TPDO indexes is selected and the newly created object index is used as the data to be transmitted in the content of this TPDO. Thus, the transmission of the relevant object dictionary entry on the network via TPDO messages is configured. The structured version of the TPDO content to include the newly created object dictionary entry is shown in Figure 5. In order for the process to be completed, the necessary software files are updated using the “File >> Export CANopenNode” option and the configuration for the TPDO broadcast is completed.

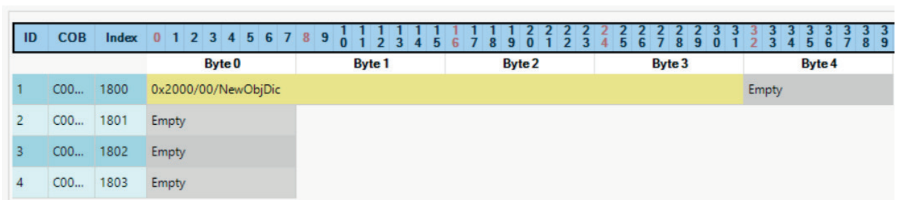

Figure 5. TPDO configuration and mapping of the newly defined object dictionary entry to PDO messages in the CANopenEditor interface

CIA-417(CAN In Automation - Lift)

The CIA-417 profile is based on the modular development of elevator systems and offers a structure consisting of eleven basic units. The units in question are defined as call controller unit, input panel unit, output panel unit, car door controller unit, car door unit, light obstacle detection unit, car driver controller unit, car driver unit, car position unit, load measurement unit and remote data transmission unit. The CIA-417 profile minimizes compatibility problems for system integrators and increases the efficiency of product development processes by providing manufacturer-independent and uninterrupted communication between these units.

The modular structure offered by the profile allows elevator components of different brands and models to be easily integrated into the system, thus enabling the development of customizable and scalable system designs. In this context, CIA-417 supports the implementation of decentralized and distributed control architectures, offering a simpler infrastructure compared to traditional cabling methods. This reduces the overall complexity of the system and significantly reduces maintenance costs.

Real-time data transmission, which is of critical importance in elevator control systems, is provided with high reliability via the CIA-417 profile. This feature offers significant advantages in terms of passenger safety and system performance. In addition, the error diagnosis and fault management features provided within the framework of the CANopen protocol have been specially adapted to elevator applications with CIA-417, allowing for rapid and effective detection of possible faults in the system. In addition, it has become possible to effectively manage remote monitoring and maintenance processes.

The CIA-417 profile has become one of the standards that the elevator industry globally, especially in Europe, takes as a reference. This provides a significant advantage for manufacturers in terms of competitiveness in the international market. CIA-417, which responds to basic requirements such as standardization, flexibility, cost-effectiveness and reliability, is considered a communication protocol that should be preferred primarily in modern elevator systems, as it offers ease of integration, effective management of maintenance processes and a high-performance communication infrastructure for both manufacturers and end users (Feiter et al., 2013).

RESULTS

The panel prototype developed with the supplied motherboard was operated synchronously and the communication compatibility of the system was tested with the CAN analyzer. All tests and experimental analyzes were carried out at BUTKON R&D center (BUTKON, 2025). PDO broadcasts and data reception were successfully performed via the panel, call recording and floor display functions worked. In the field tests conducted on the pilot elevator system, the device worked as plug-and-play and no communication error was observed. In addition, the system's remote software update and parameter adjustments were made possible.

The communication process between the developed product and an elevator controller that complies with the CIA-417 profile was analyzed. Time-based evaluations were made based on the data obtained using CANopen Magic Professional software. As a result of the examinations, it was determined that the average response time of the broadcasted NMT and SDO messages was 1.2 milliseconds. In addition, during the NODE-ID scanning process performed by the elevator controller at the beginning of the system, the average device detection time was observed as 0.9 seconds. In the analysis conducted on 10,000 messages sent to evaluate the transmission reliability, it was determined that no data loss occurred and all messages were successfully responded to. When an erroneous message packet was created and sent with TPDO, it was observed that the erroneous data packet was detected and the feedback time to the system was a maximum of 10 milliseconds. These results show that the system operates with high compatibility and reliability with other components integrated into the CANopen network structure. The developed system was integrated into elevator systems of different brands and models and subjected to field tests. Pilot applications were carried out on both passenger and freight elevators, taking into account different building typologies and traffic densities. The performance data obtained are summarized as follows:

- System integration time was 30% shorter on average compared to existing elevator control systems.
- Call detection and feedback time was found to be satisfactory in terms of user interaction, remaining under 100 ms.
- Thanks to the flexible configurability of the panel interface, 100% functional compatibility was achieved in different building scenarios.
- In all applications, the system's impact on data traffic over the CANopen network was minimal, and no deterioration in network stability was observed.

In general, the findings show that the proposed design both provides technical compliance with the industry standard and supports operational efficiency in the field. In this context, the study presents an exemplary application model for modular, adaptable and sustainable control panel designs in elevator systems.

CONCLUSION AND DISCUSSION

This study aims to develop a local call and display panel prototype that is fully compatible with the CANopen-Lift (CIA-417) standard. In short, a system has been designed that makes the display panels used in elevators more reliable, flexible and compatible. The developed prototype has successfully passed both software and hardware tests and has proven its reliability by providing error-free real-time data transmission.

Compared to traditional panels, this new design has significant advantages. Since it has a more modular structure, it is much easier to install and maintain. In addition, thanks to the use of open-source CANopenNode software, development costs have been reduced and rapid prototyping has been provided. In field tests conducted in a real elevator environment, it has been observed that the system works reliably and no communication errors have occurred. Moreover, thanks to remote software update and parameter adjustment features, maintenance processes will be easier, thus reducing the need for physical intervention in the field.

Moreover, the fact that a developed elevator panel complies with the CIA-417 standard ensures that it works seamlessly with control units from different manufacturers. In other words, compatibility and scalability are ensured between various systems used in the sector. When the developed system is compared to existing commercial solutions, it draws attention with its suitability for domestic production, low cost and compliance with international standards.

Of course, the system also has some shortcomings. It currently only works with a wired connection and therefore features such as wireless software update or cloud integration are not yet supported. However, in future versions, remote monitoring and maintenance of the system will be possible with the addition of IoT technologies or wireless communication protocols such as Wi-Fi. In addition, reliability and efficiency can be further increased with artificial intelligence-supported failure prediction systems.

As a result, this developed elevator panel reveals the importance and advantages of communication standards used in the sector. The study provides a solid foundation for developing smart elevator systems. It also contributes to domestic production by reducing dependency on imported technology.

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Conflict of Interest

The authors have declared that there is no conflict of interest.

Author Contributions

Eyup Sayin: Methodology, investigation, visualization, writing.

Murat Topuz: Validation, Methodology.

Muhammet Fatih Aslan: Writing, supervision.

Akif Durdu: Supervision.