Mini-factory
Dubina

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Preface

This book is about a mini-factory for the small-scale production of the Evo electric sports car. It is aimed at everyone interested in industrial design, production management, and the creation of manufacturing spaces. The material is presented in a practical manner and can be considered a textbook, a conceptual project, or a blueprint for a real enterprise. It provides a consistent and detailed description of the mini-factory building structure. When I was designing the Evo car, I contemplated how to manufacture it and what technologies and equipment would be required. I dreamed of my own manufacturing facility and focused on small-scale production. As the project progressed, the factory layout was reconsidered and refined. The result is a compact manufacturing building with the most minimal footprint possible for car production. The building's structural form is derived from the requirements of the technological process and meets standards for strength, stability, and durability. The construction utilizes the latest manufacturing methods that satisfy requirements for material efficiency, industrial production, and rapid assembly. Standardized products manufactured using cutting-edge methods are widely used in the structure. Both production and domestic facilities are accommodated within a single building with a total area of 960 square meters. The floor plan, the organization of the assembly hall, the positioning of production stages, and the choice of engineering systems are shaped by the actual tasks of small-scale car manufacturing. By reading this book, you will discover how a modern manufacturing facility is organized. The production process here offers flexibility, innovation, and the ability to rapidly improve the design directly during the workflow. You will see the factory from the inside: from the powerful steel framework and sun-drenched workshops to the director's office, where the company's development course is charted. The book introduces the mini-factory personnel—a team of sixteen people working in sync, like a single sports team. Special emphasis is placed on the interaction between the people running the production, the role of each specialist, and how their collaborative effort transforms an idea into a finished product. This book is a guide to a world where engineering thought takes shape, where every nut and every byte of code matters, and where a small team is capable of creating grand and complex machines.

1 General information about the mini-factory

The mini-factory was designed for construction in a humid subtropical climate, with an average annual temperature of +12 °C, characterized by long hot summers, short warm springs, and mild but relatively dry winters. The mini-factory is a single-story building with a total area of 960 sq. m., featuring a height of 4.7 m to the bottom of the load-bearing structures and a ridge height of 5.6 m (Figure 1).

Figure 1 – Mini-factory Dubina

The factory building houses a production hall, administrative offices, and a canteen. The production hall includes a production line consisting of five stages. The manufacturing process throughout the factory is monitored by surveillance cameras. The first production stage involves welding. The second stage is the assembly of the battery pack. The third stage of the production line involves the moulding and assembly of composite material parts. After polymerization, the mould with the part proceeds to the fourth stage for demoulding and machining. Following machining, the part arrives at the fifth and final stage of car assembly, which takes place at a single workstation. All body parts are assembled there. Two workers install all vehicle equipment and mount the electrical wiring in a specific sequence. Assemblers equip the body with the powertrain, battery, and instrument panel. Once the parts are installed, workers verify the operation of all vehicle systems. After assembly, the vehicle enters the paint booth. After the paint is applied, hot air is supplied to the booth for drying. Following the painting process, the vehicle undergoes a final quality check (Figure 2). The factory personnel operate like a single sports team. The team is led by the factory director. The entire team consists of sixteen people: Factory Director, Senior Designer, Junior Designer, Senior Technologist, Junior Technologist, Senior Hardware Programmer, Junior Hardware Programmer, Senior Web Programmer, Junior Web Programmer, Assembler, Machine Operator, Electrician, Welder, Moulder, Painter, and Household Worker.

1 – Column; 2 – Roof purlins; 3 – Entrance gate; 4 – Wall; 5 – Windows; 6 – Exit gate; 7 – Downspout; 8 – Entrance door; 9 – Canopy; 10 – Paint booth; 11 – Stairs; 12 – Split system; 13 – Air duct.

Figure 2 – Structural elements of the mini-factory

2 Factory structure

2.1 Framework

The load-bearing framework of the 48 x 20 m mini-factory building consists of variable-section steel frames, comprising columns and beams, as well as a system of wall and roof purlins (Figure 3). Variable-section I-beam steel columns, manufactured by electric welding from 2 cm thick steel plate, are the load-bearing elements of the metal framework, absorbing the primary loads on the clear-span building. Each steel column consists of a shaft, a cap, and a base, with a 12 m spacing, a width of 20 m, a height of 4.7 m to the bottom of the load-bearing structures, a ridge height of 5.6 m, and a roof slope of 4°. Column components are welded at a specialized facility and shipped ready-made to the construction site. All elements of the primary load-bearing framework are coated with an 80 μm thick primer to protect against corrosion during transportation, installation, and operation.

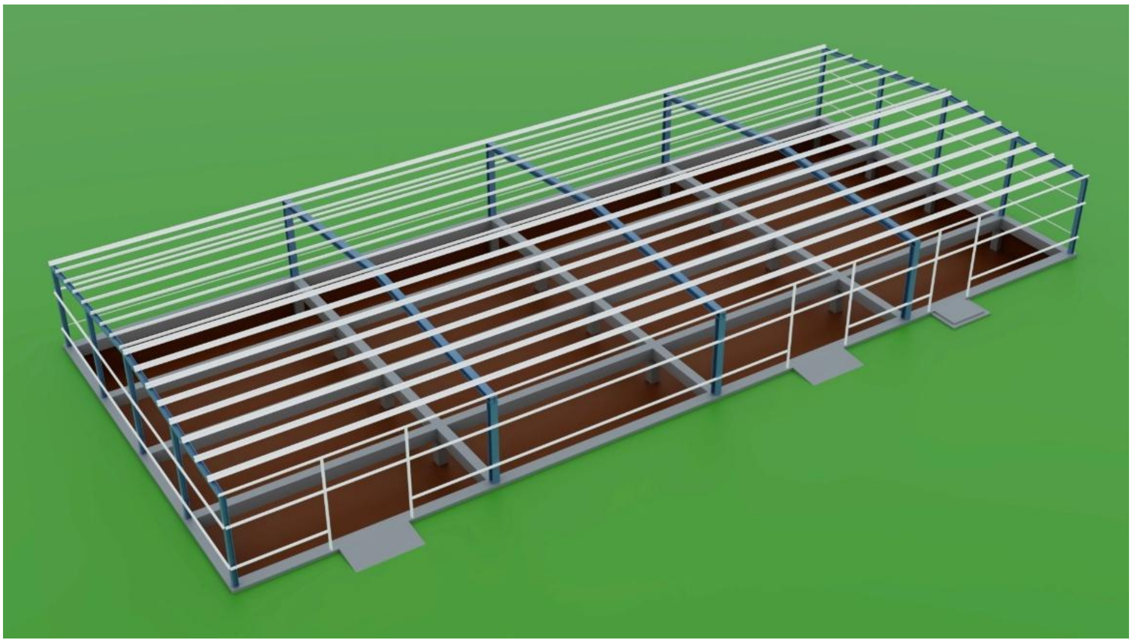
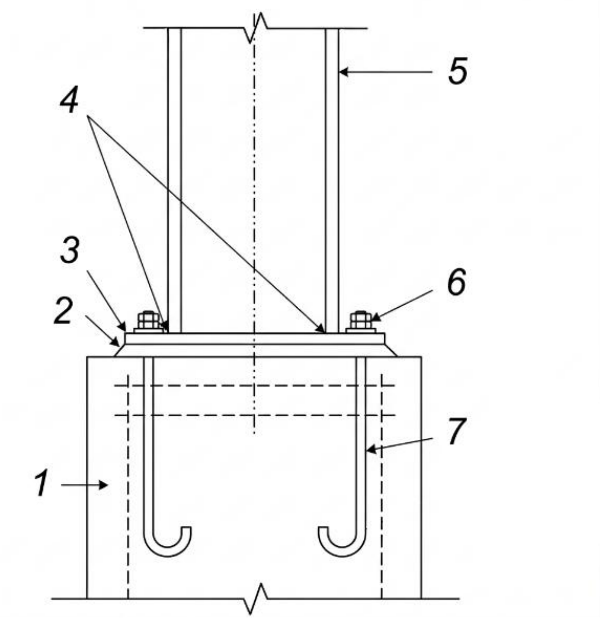


Figure 3 – Mini-factory building framework

The load from the building framework is transferred to the foundation through the base of the frame; the building frame has a rigid connection to the foundation. Rigid column support ensures the transfer of lateral and bending moments, creating a stable structure. The steel column is attached to the foundation using anchor bolts and a base plate, which is made of a 500 × 500 × 20 mm steel plate and welded to the base of the column (Figure 4). The base plate distributes the load from the column over a larger foundation area, preventing point loads. Anchor bolts serve to fix the column's position and transfer tensile forces arising from bending moments into the foundation. The column base is designed for the uniform distribution of concentrated pressure from the column to the foundation surface and guarantees the fixation of the lower end of the column in accordance with the established design scheme.



1 – concrete foundation; 2 – grout; 3 – base plate; 4 – butt weld;
5 – steel column; 6 – double lock nuts and washer;
7 – anchor bolt.
Figure 4 – Column-to-foundation connection.

2.2 Roof

A double-layer steel standing seam roofing system with an insulation thickness of 120 mm is used on the roof (Figure 5). The inner panel provides an aesthetic appearance inside the building, acts as a vapor barrier, and enhances the fire resistance of the roofing system. It offers the advantages of a system with an additional framework and is suitable for rooms with high relative humidity.

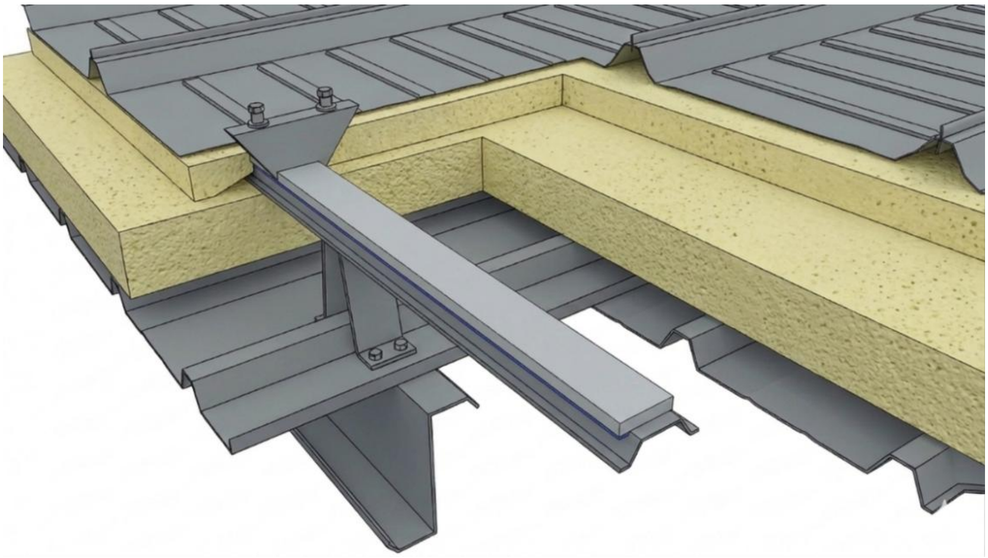
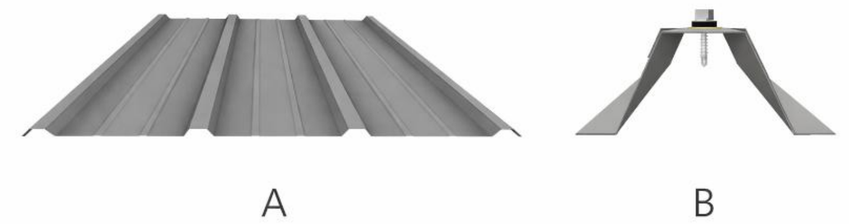


Figure 5 – Double-layer steel standing seam roofing system

The roof utilizes factory-rolled panels with a width of 1 m. The fastening system allows for the longitudinal movement of the panels during seasonal thermal expansion. Transverse ribs provide additional stiffness to the panels. The panel material is 0.75 mm thick galvanized steel with a zinc mass of 275 g/m² (Class 1). This ensures decades of corrosion protection; the coated steel panel does not crack at bends and is UV-resistant. The panels are attached to the roof purlins using stainless steel self-tapping screws with polymer caps matching the color of the panels (Figure 6).



A – Roofing panel; B – Joining method
Figure 6 – Roofing panel and its joining method

The building's roof purlins are horizontal beams that are part of the roof's metal structure and serve to distribute the load from the roof to the columns. They ensure the strength and stability of the roof and are also used for mounting lighting fixtures and the ventilation duct (Figure 7).

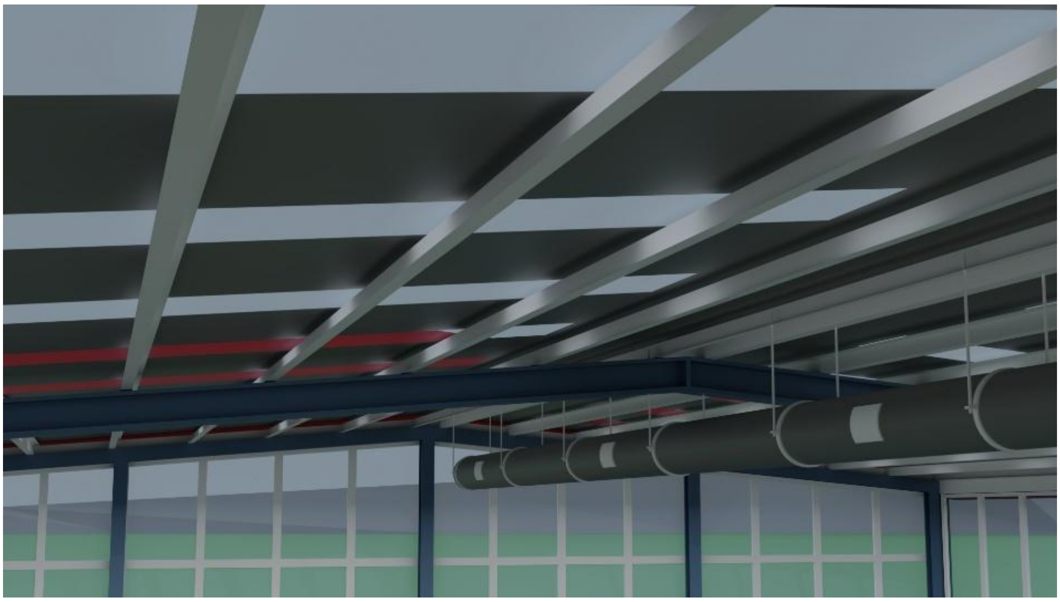


Figure 7 – Roof purlins

Skylights (mansard windows) are installed on the roof directly in the plane of the slope at the same angle as the roof (Figure 8). Special flashings for standing seam roofs are used for their installation, ensuring a watertight connection with the metal panels. For a steel standing seam system, it is critically important to use watertight flashings designed specifically for flat metal coverings to prevent leaks at junction points.

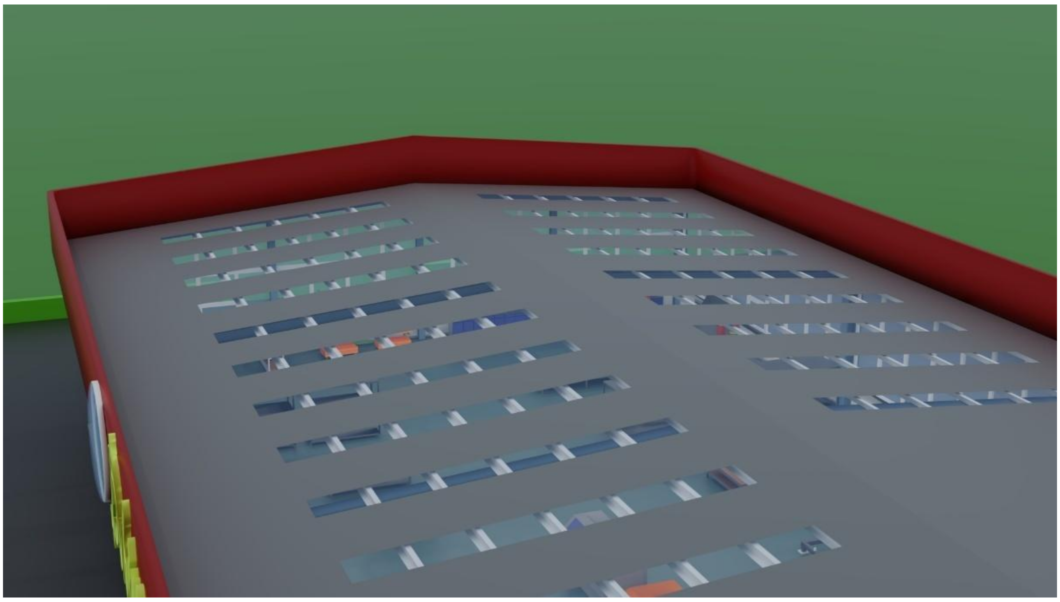


Figure 8 – Skylights on the roof

2.3 Walls

The walls are curtain walls; they are loaded only by their own weight and wind loads within the floor level and transfer the load to the building's framework. Wall systems consist of profiled steel panels attached to the secondary framework using self-tapping screws with polymer caps matching the color of the panels (Figure 9). The installation of panels requires less labor, and their cost is lower than that of brick walls.

Figure 9 – Mini-factory wall

Installation of the internal wall panel provides protection for the thermal insulation against possible mechanical damage and improves interior aesthetics. A perforated panel is used, which features increased sound absorption. The internal wall finish conceals the elements of the secondary framework. Ventilation grilles, opening trim elements, and decorative accessories are mounted within the wall panel. Advantages of wall panels include: aesthetic appearance, high-quality coating, simple and rapid installation, easy replacement of damaged panels, a wide range of adapted accessories, a full set of trim details and elements, cost-effectiveness, functionality, and durability.

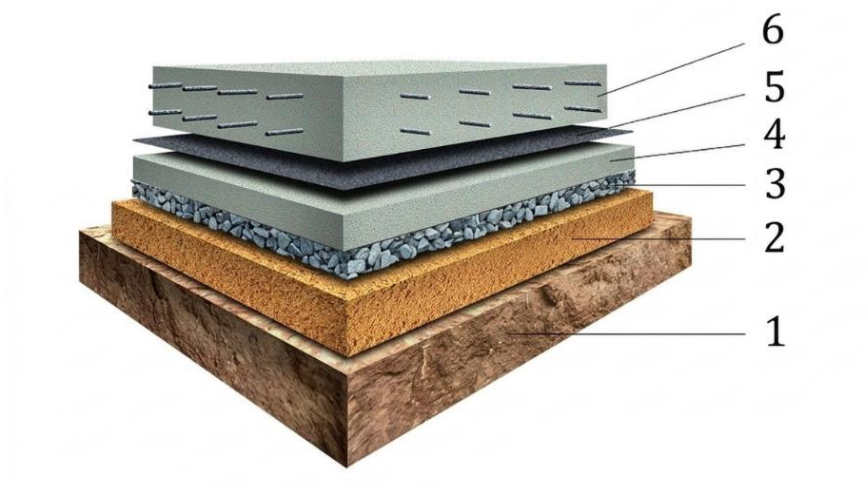
Wall purlins (girts) are used to support the wall panels, cladding, and windows. Wall purlins (horizontal beams) distribute loads to the building's framework. They are an important element of the building framework and are manufactured from steel. Wall purlins are made of cold-formed galvanized Z-profiles. Installation is carried out using galvanized bolts. Openings are constructed from galvanized cold-formed L, C, U, and Z profiles. All elements of the load-bearing framework are shot-blasted and coated with an 80 μm thick primer to protect against corrosion during transportation and installation.

2.4 Heating

To ensure a comfortable temperature at the factory in a humid subtropical climate, a system of sixteen electric convectors with a total capacity of 32 kW is used. Given the mild winters and an average air temperature of +12 °C, such a system is optimal for maintaining the working microclimate. Each convector has a power output of 2 kW. This modern heating device is enclosed in a steel housing shaped like a rectangular parallelepiped with dimensions of 120 × 60 × 6 cm. The convector features a large heat-exchange surface area despite its slim profile. Cold air intake vents are located at the bottom of the housing, while louvers for the heated airflow exit are at the top. An innovative X-shaped monolithic heating element made of aluminum alloy allows the device to reach operating temperature quickly and heat the air silently without over-drying it or burning dust. The control unit includes an electronic thermostat and a power mode switch for precise temperature maintenance, allowing for flexible regulation of the building's temperature and the factory's energy consumption. Internal tip-over and overheat protection sensors provide an immediate electrical circuit break in case of an emergency. The operation of the convector is based on the physical law of natural air convection. Cold air at the bottom of the room enters the device through the lower vents. As it passes through the blades of the heating element, the air warms up. Heated air becomes lighter, expands, and rises through the upper louvers due to natural draft. Rising to the ceiling, the warm air gradually cools, descends, and enters the convector again. This creates a continuous circulation of warm air that effectively heats the building's interior space. Using convectors with an IP24 splash protection rating reliably protects the electronics from condensation. The electronic thermostat and auto-restart function allow the system to resume operation independently with preset settings even after brief power outages, which is vital for an uninterrupted production cycle. Sixteen such units with a total capacity of 32 kW effectively compensate for heat loss through the factory's glazing and gates, creating a stable thermal environment for engineers and technicians. The heating system operates on a temperature schedule with a "night mode." The use of programmable thermostats integrated into a single climate control system makes the enterprise efficient. Climate control for the factory saves energy while constantly monitoring indoor temperatures. Reducing the temperature by just 1 degree saves approximately 7% of electricity. A constant temperature without fluctuations improves health and reduces the risk of colds. Furthermore, a stable temperature extends the service life of equipment and protects electronics from the humidity of the subtropics. Condensation forms on cold surfaces. If the car's metal frame or a machine tool is colder than the air in the workshop, they will become covered in water droplets. Constantly maintaining the temperature above +12...+15 °C at night prevents the equipment from cooling to the critical point where moisture begins to condense on it. According to sanitary standards and technological production requirements, the recommended temperature for offices and administrative areas—where work is sedentary and physical activity is minimal—is between +21 °C and +23 °C during working hours to ensure employees do not get cold. This is the temperature at which the brain functions productively and the body does not overcool. In the assembly hall, where the main production takes place, people are moving, and the equipment generates some of its own heat. During working hours, the temperature there is maintained between +18 °C and +20 °C. This is an ideal temperature at which workers do not overheat while moving, and it is the optimal mode for the precision of CNC machines. At night, the temperature throughout the building is set between +12 °C and +14 °C. This is sufficient to prevent condensation on metal without wasting excess energy. For "by-the-hour" automation, a "smart factory" system with programmable thermal regulators is used: 08:00 — Start of the shift: temperature in the workshop +19 °C, temperature in the engineering hall +22 °C. 17:00 — End of the shift: transition to "night mode," the thermostat switches to maintain an indoor temperature of +13 °C. 06:00 — Automatic activation of convectors at full power to pre-heat the building after the night to +19 °C in the workshop and +22 °C in the engineering hall.

2.5 Floor

A structural element recessed below the ground surface that absorbs loads from the building and transfers them to the base is called a foundation. The factory foundation is a pad foundation (column foundation) with a grade beam (rostverk) and a slab-on-grade floor. The soil at the foundation site consists of semi-solid loams and clays. The bearing capacity of the soil beneath the footing of the pad foundation is 200 kPa (1.5–2.0 kg/cm^2). The soil withstands the loads from columns and grade beams, transferring them evenly without excessive settlement. The reinforced concrete grade beam is monolithic, with a height of 700 mm and a width of 500 mm, constructed at the floor level. The floor is independent of the grade beam. The slab-on-grade is not rigidly connected to the grade beam; instead, it is separated by an expansion joint—a 20 mm thick strip of PSB expanded polystyrene. Foundation settlement is not transferred to the floor. The grade beam and pad foundations absorb the loads from the columns and the framework, while the floor absorbs the loads from equipment and loading vehicles. The floor consists of a compacted base of sand and crushed stone with a thickness of 400 mm (Figure 10). Then, a 100 mm thick lean concrete bed (class B7.5) is laid upon it, followed by a waterproofing membrane, and finally, a concrete screed (class B22.5) reinforced with A500C welded wire mesh (Ø10 mm with a 200 × 200 mm pitch). The upper and lower mesh zones are set on chairs (spacers). The thickness of the screed is 150 mm.



1 – soil; 2 – sand; 3 – crushed stone; 4 – lean concrete;
5 – waterproofing; 6 – concrete screed.
Figure 10 – Building floor.

The concrete bed (lean concrete) serves as an intermediate layer between the compacted base and the screed. This preparation layer is designed to protect against groundwater and to provide additional pressure distribution onto the soil. For the concrete bed, B7.5 concrete with a low stiffness class is used, as the strength requirements for this layer are less demanding. In this case, the lean concrete performs the following functions: it prevents the cement paste from leaking into the soil, ensuring the required strength of the monolithic floor screed; it levels the site and provides convenience for the installation of the reinforcement cage and the monolithic screed; it acts as an additional shock absorber during minor soil deformations, thereby protecting the base structure.

Next, waterproofing is laid over the lean concrete, and the screed is poured on top of it. A topping is applied to the surface of the floor screed to create an ultra-strong, wear-resistant, and sealed finish layer. The final floor covering is a polyurethane coating, chosen for its strength, chemical resistance, and ease of maintenance. This is a seamless polymer coating based on polyurethane resins. It forms a dense, slightly textured surface with high wear resistance and multi-colored markings. The polyurethane coating offers: high strength and wear resistance; resistance to impacts and abrasive loads; resistance to chemicals (oils, fuels, weak acids, and alkalis); elasticity (it does not crack under vibration or temperature fluctuations, unlike epoxy coatings); seamlessness and airtightness (no crevices where dirt can accumulate); and durability (10–15 years under normal operation). The total thickness of the coating is 3 mm.

2.6 Doors

A metal swing door with windows is installed at the main entrance of the mini-factory building (Figure 11). Within the assembly hall, metal doors with small windows are installed. Interior doors are fitted for the engineering hall, the director's office, the meeting room, the restroom, and the cafeteria. Metal doors are installed for the locker room and the paint booth preparation room.

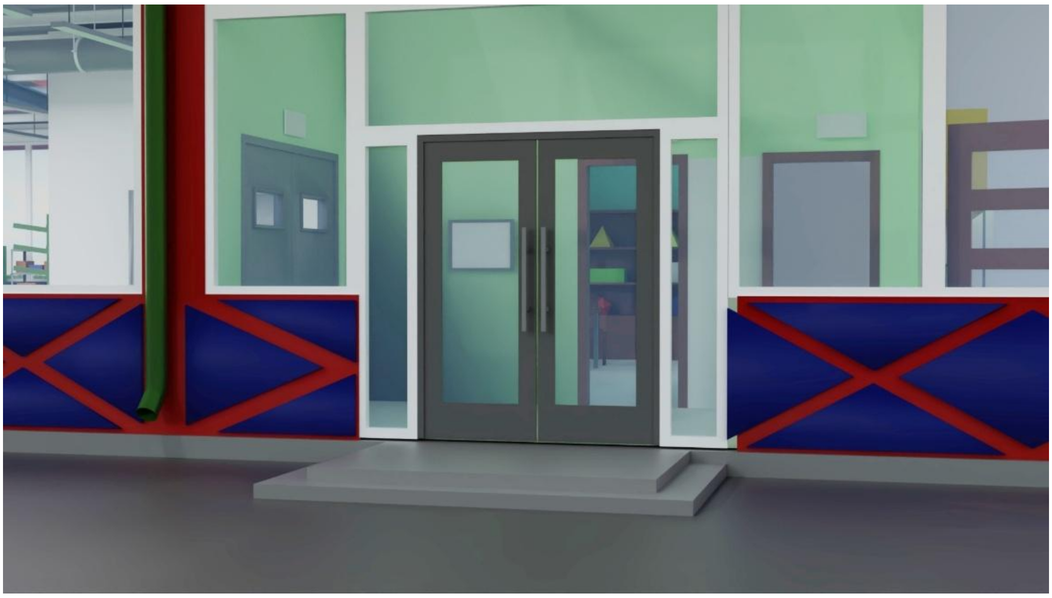


Figure 11 – Main entrance door

2.7 Gates

The factory utilizes automatic roller shutter gates (Figure 12). They are used for loading parts and equipment, as well as for unloading finished products. The first gate is located in front of the assembly area, and the second gate is positioned in front of the warehouse. The gate height is 2.5 m, and the width is 3 m. The operating principle of the gates is similar to window shutters. Metal guide channels (C-channels) are located on the walls of the opening, within which the gate curtain moves up and down. A housing box is situated above the channels, where the gate curtain is coiled. The coiling system consists of an octagonal shaft with the edge of the curtain attached to it, along with a mechanism that rotates the shaft in either direction to open or close the gate. This mechanism is controlled by an automatic system via a remote control. The gates are also equipped with a manual override mechanism installed in case of an automatic system failure. The curtain consists of durable aluminum slats, 23 mm thick and 80 mm high, filled with rigid polyurethane foam, which provides the thermal insulation properties of the gate system. The slats are interconnected using factory hinges. Aluminum slats are lightweight and rust-resistant. The service life of aluminum gates exceeds that of plastic and steel structures. Unlike swing gates, these do not require free space for opening. The roll coils vertically upwards and does not require additional space to open. Roller shutter gates are also more convenient compared to sliding gates because no opening/closing mechanism needs to be mounted on the ground. However, the design of such gates has many gaps through which warm air escapes the building; therefore, they are used in relatively warm climates.

Figure 12 – Roller shutter gates

2.8 Stairs

A service ladder is provided at the rear of the factory building to provide access to the roof (Figure 13). It is designed for roof maintenance: cleaning gutters and windows, inspecting the condition of the roofing material, and providing access to ventilation equipment and external split-system units. The ladder structure is rigidly attached to the building framework's wall purlins (girts). It is manufactured from steel profiles and painted for corrosion protection. It is engineered for operational loads and equipped with anti-slip steps, ensuring a safe climb during any season. Restricted access prevents the ladder from being used by unauthorized persons. Roof access is organized through a service hatch equipped with a locking mechanism. This allows for controlled access and prevents unauthorized entry. Having a dedicated ladder simplifies the maintenance of engineering systems, reduces work time, and increases the overall operational safety of the factory building. Roof access via the ladder allows for the prompt execution of seasonal tasks, such as clearing snow or foliage, without the need for specialized lifting equipment.

Figure 13 – Service ladder to the mini-factory roof

2.9 Cornice

A significant architectural feature of the building is the massive cornice, which serves as a harmonious extension of the roof (Figure 14). On the front side of the factory, it extends forward by 2 meters, forming a kind of canopy over the front facade. This solution not only protects the entrance area and the adjacent part of the foundation from precipitation but also creates a striking visual accent. The structure's finished and modern appearance is enhanced by a 1-meter-high decorative trim (fascia) that runs along the entire perimeter of the cornice. This parapet conceals the structural elements of the roof, engineering utilities, and drainage system, creating a neat and cohesive exterior for the building. The cornice gives the factory a disciplined, monumental look, transforming an industrial building into an aesthetically attractive object of modern architecture.

Figure 14 – Building cornice

2.10 Climate control system

The factory's ventilation and air conditioning system is a vital element of the engineering infrastructure, ensuring safe, comfortable, and technologically correct working conditions throughout all areas of the enterprise. Its design and operation account for the specific requirements of small-scale car production, including welding, painting, assembly, and office zones, as well as air quality and thermal regime standards. Supply and exhaust ventilation is utilized in the production hall, providing a constant intake of fresh air and the removal of contaminated air. In welding areas, local exhaust ventilation is installed to remove welding fumes, smoke, and aerosols directly at their source. The paint booth utilizes a separate, specialized ventilation system with filtration, ensuring a directional airflow, removal of paint vapors and solvents, and maintenance of the specified temperature and humidity during painting, drying, and cooling modes (Figure 15). The ventilation control for the paint booth is located in a dedicated equipment room, which enhances safety and reduces the risk of ignition and air contamination.

Figure 15 – Heat exchangers of the climate control system

In the assembly area, ventilation is designed to dissipate heat from equipment and maintain comfortable conditions for personnel. Airflows are organized to prevent drafts and avoid kicking up dust, which is particularly critical during vehicle assembly. In administrative and engineering rooms, an air conditioning system is used to maintain a stable temperature and a comfortable microclimate for employees. Air conditioners and supply units provide air filtration, as well as temperature and humidity regulation. All ventilation and air conditioning systems are integrated into a single control scheme, allowing for the adjustment of operating modes depending on the production process, season, and room occupancy. The reliable operation of these systems ensures personnel safety, technological process stability, and the high quality of the products manufactured by the factory.

2.11 Drainage system

The building's drainage system is designed according to an organized scheme and is intended for the effective removal of rainwater and meltwater from the roof surface. Semicircular gutters are installed on the roof slopes and along the cornice line; they collect water evenly across the entire length of the roof and direct it to flow convergence points, where the gutters connect to the funnels of the vertical downspouts (Figure 16). This shape of the gutters ensures a steady flow of water and reduces the risk of overflow during heavy precipitation. On the horizontal edge at the bottom of the cornice slope, the semicircular gutters are installed with a slope towards the corners of the building. In these locations, water from the gutters enters the vertical downspouts. The corner placement of the intake sections allows for a compact drainage organization and keeps the facades clean without disrupting the building's architectural appearance. Through the vertical pipes, water flows by gravity downwards into a drainage ditch located along the building. The drainage ditch ensures the collection and distribution of runoff, preventing soil erosion near the foundation. Additionally, a drainage ditch is located along the perimeter of the parking area; it is situated at a slight 3° angle relative to the building's lowest point to ensure that rainwater does not stagnate in the parking lot or flow toward the mini-factory building. The collected water is diverted into the stormwater drainage system, which eliminates its accumulation on the factory grounds and provides reliable protection for the building and adjacent areas against excessive moisture.

Figure 16 – Roof and site drainage elements

2.12 Sewage system

The factory's sewage system is a comprehensive engineering network designed for the disposal of domestic, industrial, and surface wastewater from the enterprise territory. The system is designed considering the functional zoning of the building, technological processes, and environmental and sanitary safety requirements. It is divided into two primary circuits: the domestic (sanitary) sewer and the storm sewer. The internal domestic sewage system serves the restrooms, locker rooms, canteen, and domestic premises. Wastewater from sinks, showers, toilets, and kitchen equipment is directed by gravity through a piping system into a common sewer manifold. Sewage lines are positioned to avoid intersecting with production zones and to provide convenient access for maintenance and repair. Special attention is paid to production areas such as the paint booth and the moulding area. Direct discharge of technological fluids into the common network is prohibited; all chemical waste is disposed of according to safety protocols, ensuring the environmental integrity of the factory's operations. The storm sewage system is designed to collect rainwater and meltwater from the roof and the factory grounds. Water from the downspouts enters the drainage ditches and is then directed into the storm sewer system. This scheme prevents water stagnation, soil erosion, and excessive moisture around the foundation. All elements of the sewage system are integrated into a single network, ensuring the reliable and uninterrupted disposal of effluents. The factory's sewage system contributes to the maintenance of sanitary conditions, environmental protection, and the stable operation of the production complex as a whole.

2.13 Lighting

Lighting in the factory is provided by a combination of natural daylight and artificial light. During daylight hours, natural lighting predominates thanks to large windows located around the building's perimeter and in the roof, through which sunlight penetrates all areas of the factory. Windows are present in every room of the facility. In the locker room and restroom, windows are positioned at a height of 2.5 m. This ensures a sufficient level of illumination during the day without the need for constant use of artificial light. Artificial lighting is provided by LED lamps. In the assembly hall, engineering hall, and domestic premises, fifty-seven rectangular LED lamps with a power of 100 watts each are suspended from the metal purlins (Figure 17). These fixtures are 300 cm long and 20 cm wide, with a color temperature of 5000 Kelvin. This corresponds to daylight white light and ensures accurate color rendering during assembly work. Seven lamps are installed in the engineering hall, creating equally bright and uniform illumination for the workstations. The paint booth uses special protected and sealed light fixtures mounted into the walls and ceiling. They are designed to operate in conditions with high concentrations of aerosols and provide uniform illumination of all surfaces for high-quality painting operations. The doors of the paint booth feature windows that allow sunlight or light from the assembly hall lamps to pass through. Above the building entrance and the entrance gates, LED lamps are suspended under the cornice to provide good visibility on the factory grounds during the dark hours.

Figure 17 – Lighting lamps in the workshop

2.14 Electrical wiring

The factory's electrical wiring is an extensive engineering system that provides a reliable and safe power supply to all production, engineering, and domestic premises. It is designed considering the high energy intensity of the equipment, the continuity of technological processes, and industrial safety requirements. The main power input is routed through the main switchboard located in the technical zone. From there, power cables branch out into power and lighting circuits. The power wiring is intended to supply production equipment, welding machines, ventilation units, and the heating system. To protect against mechanical damage and environmental factors, and for ease of maintenance, all wiring in the production workshops is routed through special metal cable trays under the ceiling and within protective corrugated conduits along the walls. The assembly hall is equipped with 380 V power connectors for industrial equipment and 220 V outlet groups for handheld power tools. Each group of consumers is protected by individual circuit breakers and residual current devices (RCDs) in local distribution boards, allowing for repairs in one area without de-energizing the entire factory. The lighting wiring is configured in separate groups, ensuring the operation of LED fixtures throughout all factory premises. Lighting control is organized by zones, enabling economical energy use and the adaptation of illumination to current production tasks. In rooms with special operating conditions, protected cables of the appropriate class are utilized. Low-voltage systems include communication lines, internet, video surveillance, security and fire alarms, as well as control networks for engineering equipment. These lines are laid separately from power cables to reduce electromagnetic interference and enhance equipment reliability. Particular attention is paid to the grounding and potential equalization system. All metal structures, equipment, and electrical installation housings are grounded, ensuring personnel protection against electric shock. The electrical wiring is installed in compliance with regulatory requirements, designed for long-term operation, and ensures the stable and safe performance of the factory as a whole.

2.15 Equipment and tools

The factory's equipment and tools are selected to accommodate small-scale vehicle production and ensure the execution of all technological operations—from parts manufacturing to final assembly and painting. Their layout is organized to minimize the movement of personnel and workpieces, enhance safety, and ensure ease of maintenance. Pneumatic tools powered by compressed air are widely used in the assembly hall and the paint booth. These include impact wrenches, grinders, and spray guns for applying coatings. Due to the absence of an internal electric motor, the use of pneumatic tools reduces the physical load on workers, increases operational precision, and ensures consistent quality. Compressed air is supplied by compressors located in the paint booth hall and near the car assembly station. This placement reduces pressure losses in the lines and enhances the reliability of the pneumatic system. The machining area features CNC (Computer Numerical Control) machines, including milling and turning centers. They are designed for the production of high-precision suspension and drivetrain components. Additionally, a 3D printer is located in this area, performing the printing of metal parts such as the electric motor housing and suspension knuckles. The 3D printer is indispensable in small-scale production. It allows for the rapid manufacturing of complex geometric shapes, prototypes, and small batches of components—tasks that are often impossible with traditional casting or cutting methods—without the need for lengthy equipment retooling. The welding area is equipped with a semi-automatic electric arc welding machine (MIG/MAG) used for the fabrication and assembly of metal structures, chassis frame elements, and suspension parts. The equipment is complemented by jigs and auxiliary fixtures that ensure geometric precision and the quality of welded joints. Taken together, the factory's equipment and tools form a flexible and functional production environment, allowing for the efficient execution of all car manufacturing stages while maintaining high levels of quality control and occupational safety.

3 Mini-factory layout

3.1 Assembly area

The assembly area is located in front of the production room entrance, the exit gates, and the paint booth gates (Figure 19). This layout is chosen because the vehicle assembly is performed in a single location after all parts and sub-assemblies have been manufactured. The assembly area does not overlap with other production processes. If necessary, the entire vehicle can be moved into the paint booth for painting, sanding, washing, or drying. The assembly area is marked on the floor in green with a yellow border. This marking facilitates the positioning of the vehicle for assembly, while the yellow border defines a boundary within which no equipment or tools that might obstruct the assembly process should be left.

1 – assembly area; 2 – CNC machining area; 3 – battery assembly area;
4 – warehouse; 5 – welding area; 6 – molding area; 7 – paint booth;
8 – paint booth equipment room; 9 – locker room; 10 – director's office;
11 – meeting room; 12 – engineering hall; 13 – canteen; 14 – restroom;
15 – entrance hall

Figure 19 – Factory layout

The wall with a window between the assembly area and the engineering hall visually expands the space, and the window allows for the observation of the production process, which enhances the assembly workflow. The distance from the boundary of the designated assembly area to the walls and equipment is sufficient for transport trolleys carrying large parts to pass freely without interfering with the workers performing the assembly (Figure 20).

Figure 20 – Evo vehicle in the assembly area

3.2 CNC machine area

The CNC machining area is located near the vehicle assembly zone, which is necessitated by the need for the rapid manufacturing and refinement of parts (Figure 21). This solution aligns with the concept of small-scale production, where flexibility and the ability to quickly adapt to design changes are paramount. The area is equipped with a milling machine, a lathe, a multi-axis machining center, and a 3D printer for metal printing. These machines produce engine and suspension components. Parts are moved from the machines on trolleys directly to the assembly area. Passageways are provided between the machines for the transportation of large components. The area also features a workbench, which serves as a metrology post equipped with inspection tools to ensure the precision of all parts before they reach assembly. If the assembly process reveals a need for part modification, engineers promptly transmit the adjustments to the CNC area, and a new version is delivered to the assemblers shortly thereafter. Unlike a conveyor belt oriented toward mass production, this setup represents flexible manufacturing that additionally allows for process refinement and the ability to modify the design during production. This is particularly vital for hand-built production, where experience is accumulated and technology is perfected.

Figure 21 – CNC machining area

3.3 Battery pack assembly area

The battery pack is assembled on a specialized assembly jig located in the center of the area (Figure 22). The jig is fabricated from square tubing and steel angles. There is an access point on one side of the jig to allow a trolley to exit with the completed battery. The carbon fiber battery housing is delivered from the molding area, while the battery cells arrive from the warehouse. The cells are placed into the housing and interconnected. After assembly, testing, and charging, the finished battery pack is transferred to the vehicle assembly area. The battery pack is moved from the battery assembly area to the vehicle assembly area using a hydraulic pallet jack. The pallet jack is positioned under the jig, raised to lift the battery off the stand, and then moves it to the vehicle body for installation.

Figure 22 – Battery pack assembly area

3.4 Warehouse

The warehouse is located at the end of the workshop near the building gates (Figure 23). The warehouse serves as the starting point for the entire production process; from here, parts and materials are distributed to various production areas. The racking systems hold boxes of components, tools, containers, canisters, metal profiles, and rolled materials. The warehouse also stores tires, foam boards, and raw workpieces for production. Materials and parts are transported from the warehouse to the production areas using specialized trolleys. The position of storekeeper is filled by a junior process engineer.

Figure 23 – Warehouse

3.5 Welding area

The welding area is the most productive zone, where the vehicle chassis, motor mounts, and suspension arms are fabricated (Figure 24). Electric welding is performed in an inert gas environment; therefore, gas cylinders are located within this area. In addition to vehicle parts, the welding area is used to manufacture fixtures, assembly jigs, and racking units. The area is situated adjacent to the warehouse to facilitate the rapid transfer of metal profiles, gas cylinders, and consumables. A dedicated ventilation system is installed above the welding jig to extract fumes. Two welders operate in this area.

Figure 24 – Welding area

3.6 Molding area

The manufacturing process in the molding area is the most labor-intensive. A molder takes a part matrix (mold) from the rack and places it on the molding table. The fabrication of a part begins with cutting the prepreg. Prepregs and resins are stored in special airtight refrigerated cabinets. A worker cuts the prepreg according to a pattern and places the cut material into a plastic container, which is then moved to the molding station. The molder lays the material into the matrix, covers it with a lid, and sends it to the curing area. There, the part undergoes polymerization and hardening. Afterward, the matrix is returned to the molding table to remove the finished part. Once removed, the part is sent for machining, and the matrix is returned to the mold warehouse. Since fiberglass, epoxy resin, and dust from machining can contaminate vehicle components, all sanding and finishing operations are performed inside the paint booth to prevent this. Large components requiring pre-assembly, such as the vehicle monocoque, are assembled in the pre-assembly area (Figure 25).

Figure 25 – Vehicle monocoque in the molding area

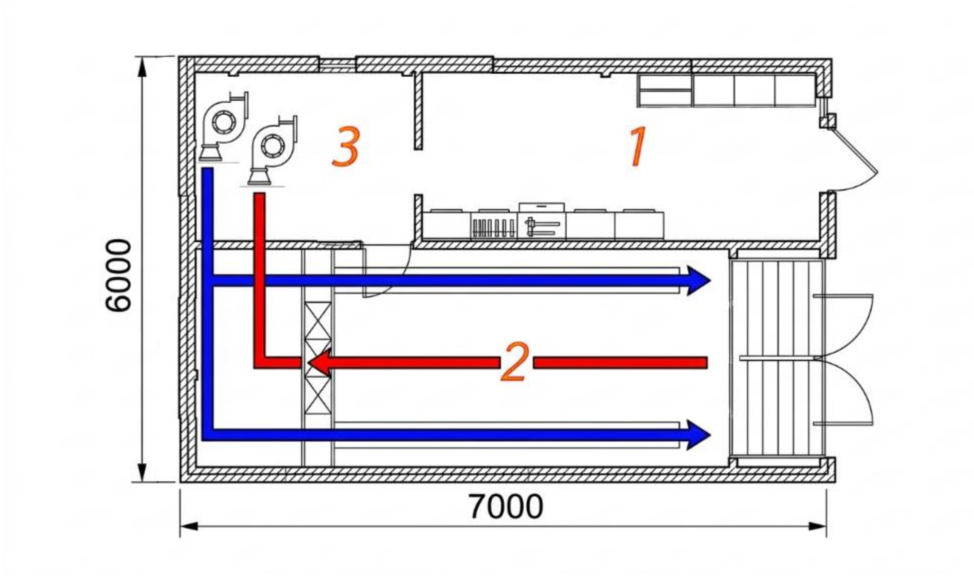
3.7 Paint booth

Painting a car body is a long and complex procedure consisting of several stages carried out in a specially designed booth (Figure 26). The body and various parts, such as the hood, trunk lid, side skirts, and bumpers, are painted here. After painting, the vehicle is returned to the assembly area, while the painted parts are placed on the assembly section racks. At the first stage of preparation involving body sanding, the ventilation system plays a crucial role. It must not only remove dust and gases from the paint booth but also filter the air supplied to it. The objective of ventilation during car body painting is to settle suspended paint particles and extract them from the booth. To achieve this, clean dry air is supplied through a dust filter via a ceiling duct, while air exhaust is handled through ducts located under the paint booth floor. This ensures that dust and gases do not rise from the floor but settle onto it. To prevent the air from drawing dust through the booth's crevices, the pressure inside the booth is maintained higher than the external pressure (positive pressure); therefore, the intake fan has a power of 2 kW, while the exhaust fan has a power of 1 kW. At the final stage, during the drying of the painted vehicle, the air in the booth must be dry to prevent condensation on the body. For this reason, the filtered air is heated to 60 °C and remains circulating within the paint booth. The lighting in the booth is uniform and shadow-free. The walls are painted in a matte white color to eliminate glare. For the operator, the clearance between the wall and the vehicle body is 1.5 m. The booth includes a preparation area containing tools and materials such as a double-atomization basecoat spray gun, a clearcoat spray gun, a primer gun, rags, and a mask. In the preparation hall, the spray guns are cleaned after painting in a gun washing station connected to the exhaust system. Adjacent to the washing area, there is a separate waste bin for solvent cans, paint and lacquer tins, and measuring cups.

Figure 26 – Paint booth

3.8 Paint booth equipment room

The paint booth equipment room is located to the right of the booth (Figure 27). It has a separate entrance from the assembly hall. The equipment room is separated from the main booth by an airtight partition with an insulated door, providing convenient access for personnel while preventing solvent vapors and dust from entering the room.



1 – preparation hall; 2 – paint booth; 3 – equipment room.
Figure 27 – Paint booth hall layout

The room provides a changing area for personnel, where coveralls, respirators, safety goggles, and gloves are stored. Clothing and equipment are kept in ventilated metal lockers. Before their shift, workers enter here to change and prepare the equipment for painting. The equipment room houses the control unit for the booth's ventilation and drying systems, a compressor for pneumatic tools—equipped with a compressed air purification and heating device—a rack for spray guns and hoses, a garment rack for specialized workwear, and shelving units for paints, polishes, sealants, sponges, and sealing spatulas. A vacuum cleaner for cleaning the booth is located near the shelves. The control units for ventilation and drying are located closer to the rear wall of the room. Workstations for system maintenance are positioned along the solid walls, ensuring clear access to the control panel. The panels, equipped with indicators and buttons, allow for the monitoring of temperature, humidity, and airflow velocity inside the booth. Air ducts leading to the filtration and exhaust systems also pass through this room.

3.9 Changing room

The changing room is located near the workshop entrance, between the assembly hall and the engineering center, making it convenient for both factory workers and engineers. The entrance to the changing room is from the assembly hall. The entrance door is situated in the wall that divides the factory into the assembly hall and the engineering center. Before starting work, employees enter the assembly hall, proceed to the changing room to change, and then go to their workstations. The changing room is designed for the use of both factory workers and plant engineers. It contains lockers for work clothes as well as a utility closet for storing janitorial and cleaning equipment. The dimensions of the changing room are 6.5 × 3.5 m. It houses 17 lockers, each measuring 0.6 × 0.5 × 1.85 m. Two benches, measuring 2 × 0.35 × 0.35 m, are placed along the length of the room between the lockers.

3.10 Director's office

The director's office is part of the engineering center. It is separated from the rest of the office area by a wall and is accessed through the engineering hall. The office features a desk with a computer, where the director works with documentation, analyzes reports, and issues orders (Figure 28). A cabinet for personal belongings stands behind the desk, while two chairs are positioned in front for receiving employees, partners, and clients. The office hosts interviews with new staff and partners, as well as meetings with engineers to solve production tasks and establish plans for the coming days. In this office, new projects are born, production schedules are drafted, strategic decisions are made, and the course of development is set. It is not merely a workspace; it is a command center, a captain's bridge. The director is not just a plant manager; he is the captain of a ship upon whom the entire production depends.

Figure 28 – Director's office

He issues technical specifications to the engineers and oversees their execution. The well-being of the entire team depends on the director. The director charts the enterprise's development course. Like a ship, a factory can sink due to emergencies. Pirates may attack the ship and steal all the technologies. Other vessels might overtake the ship and deliver goods ahead of it. A ship may find itself caught in government coups or storms and sink. It is the director's duty to ensure this does not happen.

3.11 Meeting room

The meeting room is located behind the wall of the director's office. It has a separate entrance from the engineering hall. The room is furnished with a long table and chairs (Figure 29). A large, modern interactive screen is mounted on the wall for displaying blueprints, charts, and presentations. The meeting room is used for briefings, conferences, making operational decisions, and signing contracts.

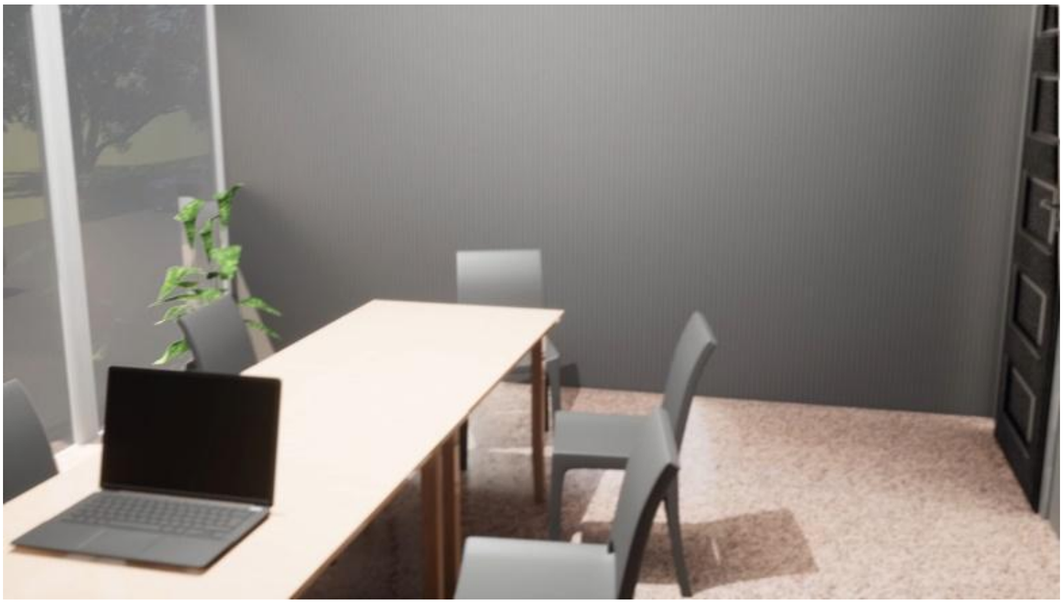


Figure 29 – Meeting room

3.12 Engineers' hall

The engineers' hall is a spacious room where design engineers, process engineers, programmers, and designers work. The hall is separated from the production workshop by a wall with windows (Figure 30). These interior windows provide a sense of greater visual space and allow for observation of the activities in both the assembly hall and the engineering hall. The desks of the process engineers are located near the entrance to the engineering hall, behind the windows. The hall contains ten desks, as well as cabinets for literature and documents. Pictures of completed projects hang on the walls. A cloakroom is located near the entrance door to the hall. The engineering hall is divided into several departments: design, electrical engineering, and software. Design engineers develop new parts and design electrical circuits, integrated circuits, and batteries. Process engineers establish the manufacturing technologies for the parts. Programmers handle both hardware programming (programming components to perform specific functions) and web development. Designers create the aesthetics, produce animations of 3D models, and design websites, advertisements, and video edits. A hierarchy of senior and junior engineers exists within the staff; for example, a senior process engineer reviews the technology documentation written by a junior process engineer. The position of deputy director is held by the senior design engineer.

Figure 30 – Engineers' hall

3.13 Canteen

The canteen is located on the right side of the factory, with the entrance situated in the front hall. Along the wall near the entrance is a kitchen area equipped with wall-mounted and floor cabinets, as well as a workspace. The kitchen features a refrigerator, microwave ovens, a sink, a two-burner electric stove, and an exhaust hood. There are four square tables with plastic chairs, providing a seating capacity for sixteen people. The furniture is arranged to ensure free movement between rows and to maintain a comfortable atmosphere during meal times (Figure 31). The table surfaces are made of moisture-resistant and durable materials suitable for daily use. The canteen is spacious and well-lit thanks to panoramic windows that offer a view of the factory parking lot and the facility grounds. Natural light creates a sense of comfort and openness. Meals in the factory canteen are provided free of charge.

Figure 31 – Factory canteen

The factory has a scheduled lunch break from 12:00 to 13:00, during which all employees can eat. Additionally, it is a factory tradition to have tea at 15:00. Lunch is prepared by a domestic staff member responsible for household tasks. She prepares daily meals considering typical preferences and the need to provide hearty and cost-effective nutrition for the employees. The menu changes daily to ensure variety. For example, the lunch menu may include: First course: Kharcho soup, borscht, or chicken noodle soup. Main course: Buckwheat porridge, pasta, or mashed potatoes served with meat cutlets, chicken or pork goulash, or fried fish. Salads: Fresh cabbage and carrot salad or Vinegret (beetroot salad). Bakery: Fresh bread. Beverages: Dried fruit compote, tea, fruit morse, or coffee. Sour cream, mayonnaise, and mustard are always available in the refrigerator. For dessert, the staff member prepares apple, pear, or banana sharlotka (sponge cake) sprinkled with ground cinnamon for a pleasant aroma. All prepared meals are portioned into special container plates and stored in the refrigerator.

3.14 Toilet

The entrance to the restroom is located in the front hall, opposite the main entrance to the factory and between the entrances to the engineering hall and the canteen. The restroom is equipped with a toilet and a washbasin. Although it is a small area, it is a vital part of the factory that is essential for the well-being and comfort of all employees.

3.15 Hallway

The entrance hall of the factory is a transitional zone that connects all the main areas of the building. Every employee passes through this hall upon entering the facility. It contains the doors leading to the production workshop, the engineering hall, the canteen, and the restroom. Above each door is a sign indicating the name of the room: Assembly Shop, Engineering Hall, Restroom, and Canteen. The hall is illuminated by an LED lamp and benefits from natural light passing through the glazed wall and entrance door. During the cold season, the entrance hall functions as a thermal vestibule, preventing warm air from escaping the building and reducing heat loss.

3.16 Parking

A paved parking lot with a total size of 64 × 16 m is located on the asphalted territory in front of the factory, designed for sixteen vehicle spaces. Each parking space has dimensions of 5.5 × 3 m and is delineated by white horizontal road markings with a line width of 0.1 m. The facility utilizes a perpendicular parking layout, where a 10-meter-wide drive aisle is maintained between the factory building and the parking zone to ensure safe maneuvering.

3.17 Barrier gate

Entry to the factory grounds is provided through a driveway equipped with a barrier gate (Figure 32). The electromechanical barrier, featuring a 4.3 m boom, is designed to automate access control to the facility. The automated system opens the passage in 6 seconds. The design of the barrier combines compactness with a sleek aesthetic. The equipment is characterized by an extended service life of 2.5 million cycles, achieved through the absence of friction in the optical sensor unit that monitors end positions. A potentiometer on the control unit is used to adjust the boom's travel limits. This device ensures high precision in setting the end positions and guarantees the correct operation of the barrier. The automation system is connected to the power supply through a circuit breaker. This method protects the device's electrical components from the negative effects of overloads and voltage spikes, while also ensuring safety during equipment maintenance. To de-energize the barrier for servicing, it is sufficient to flip the toggle switch. The barrier is operated via a remote control. A manual override handle inside the cabinet is used to raise the boom manually. Programming of the model's main operating parameters is performed by selecting commands on the control unit using DIP-switches. Special terminals are provided on the control block for connecting electrical peripherals to the barrier.

Figure 32 – Barrier gate

3.18 Hedge

A living hedge made of evergreen boxwood (Buxus sempervirens) holds a special place in the landscaping of the surrounding territory. This plant was chosen intentionally; it thrives in the subtropical climate, maintaining a rich emerald color year-round, and possesses a high foliage density that allows for the creation of perfect geometric shapes. The hedge is shaped into a strict rectangular block, 80 cm high and 50 cm wide. These proportions are specifically selected: a height of 80 cm is sufficient to visually demarcate zone boundaries without obstructing the view of the lower part of the factory facade or the parked vehicles. The 50 cm width provides the hedge with a sense of solidity and stability. The dense trimming makes it resemble a solid green wall, inviting to the touch. Despite its decorative appearance, the hedge performs several important practical tasks. It clearly separates the parking lot from the roadway and pedestrian paths. The dense foliage traps road dust and absorbs noise, creating a more comfortable atmosphere on the grounds. During periods of heavy subtropical rainfall, the hedge acts as a natural barrier, slowing surface water runoff. Against the backdrop of the factory’s metal panels, the vibrant green foliage creates a sophisticated contrast, emphasizing the modernity and cleanliness of the enterprise. Regular formative pruning is part of the factory's corporate culture. The domestic staff member is responsible for maintaining its perfect shape.

4 Mini-factory personnel

4.1 Mini-factory director

The director is the most significant figure of the enterprise; the entire production process largely depends on him. The factory must run like clockwork, and nothing should interfere with its operation. The director organizes an efficient, stable, and safe manufacturing process. On a daily basis, he plans and delegates responsibilities among the engineers. The director determines priority areas, analyzes previously completed work, and introduces modifications to projects. He conducts interviews with prospective employees and meets with clients. Possessing an advanced technical mindset and a deep understanding of all production processes, the director generates ideas, creates cutting-edge technologies, and anticipates potential challenges. He demonstrates stress resilience, accountability, and discipline. He combines strong leadership qualities with the ability to engage in dialogue and find compromises with his employees.

4.2 Senior designer engineer

The Senior Designer is the key specialist of the engineering center, serving as the acting plant director when necessary. His workstation is located adjacent to the director's office. The Senior Designer creates new products, develops and verifies engineering documentation, and oversees parts from the development stage through to manufacturing. He is responsible for quality control of manufactured components, introducing adjustments based on test results, and improving the design of existing products. The Senior Designer plans, organizes, and optimizes production processes, implements innovations to increase plant efficiency, and monitors production deadlines and quality standards. He conducts briefings with other engineers, interacts closely with the director, reviews documentation prepared by junior engineers, advises staff, and proposes modernization ideas.

4.3 Junior designer engineer

The responsibilities of the junior designer are similar to those of the senior designer. The junior designer creates new products, optimizes production processes, implements innovations, and improves factory efficiency; however, they handle less complex and high-stakes assignments. Unlike the senior designer, the junior designer does not act as a substitute for the director in his absence. The work of the junior designer is reviewed and verified by the senior designer. The junior designer prepares reports and develops engineering documentation for submission to the senior designer.

4.4 Senior process engineer

The senior process engineer develops and implements the manufacturing workflows required to produce the parts and structures designed by the engineering team. Upon receiving documentation from the designers, he analyzes the part architecture, determines the optimal manufacturing methods, and adapts the technology to the capabilities of the machine tools, 3D printers, welding equipment, assembly area, and paint booth. He ensures the manufacturability (producibility) of the products and the compatibility of all components. He prepares routing sheets (process maps) for the workers, maintains order at the workstations, and monitors compliance with safety regulations and sanitary standards. The process engineer's workstation is located adjacent to the assembly area. The senior process engineer participates in morning briefings in the meeting room, where production tasks, issues, and solutions are discussed. He proposes changes aimed at increasing efficiency, mitigates technological risks, and ensures the stable operation of the entire production line. Thanks to his work, the factory produces high-quality parts and maintains an uninterrupted production cycle.

4.5 Junior process engineer

The responsibilities of the junior process engineer are similar to those of the senior process engineer, whom they substitute for in their absence. Additionally, the junior process engineer performs the duties of a storekeeper: they accept deliveries of parts and materials, oversee their organization and storage in the warehouse, and conduct inventory audits. The junior process engineer inspects manufactured products, conducts tests on new technologies, and prepares reports for the senior process engineer regarding the work performed. They monitor compliance with safety regulations and sanitary standards and explain production technologies to the factory workers.

4.6 Senior embedded systems programmer

The senior embedded systems programmer is responsible for the development, configuration, and maintenance of the software and embedded systems used both in the production processes and within the design of the vehicle itself. He works with electronic control units (ECUs), sensors, actuators, and circuits, ensuring their correct integration into the product and the factory equipment. In addition to a desktop computer, his workstation is equipped with electronic components, microcontrollers, and circuit boards. In his daily work, the senior hardware programmer interacts with the director, who sets tasks related to the development of vehicle electronic functions and equipment automation. He collaborates with design engineers during the creation of electronic nodes, coordinating the placement of controllers and sensors. Together with process engineers, he determines the methods for programming and testing electrical equipment on the shop floor, helping to adapt manufacturing processes for electronic components and their calibration. The senior hardware programmer develops firmware for controllers, writes programs for CNC machines and test benches, creates diagnostic systems, and ensures the stable operation of the vehicle's electronics. He works in integrated development environments (IDEs) for microcontrollers, uses low-level languages (C, C++), electronic computer-aided design (ECAD) systems, and debugging tools. Essential skills include deep knowledge of electronics, circuit design, digital and analog systems, communication protocols, proficiency with microcontrollers, and experience with industrial production equipment.

4.7 Junior embedded systems programmer

The junior embedded systems programmer, like the senior, is involved in writing code for device operations, flashing microcontrollers, configuring sensors, and preparing software for production equipment; however, their work involves less complex and lower-stakes tasks. The junior programmer develops individual firmware modules, performs code debugging, analyzes simple logical errors in device operation, and conducts testing. He is responsible for executing specific tasks related to the programming and testing of electronic devices used within the factory and the vehicle design. His workstation is equipped with a desktop computer, development boards, microcontrollers, power supplies, and measurement equipment to verify the functionality of the developed code and hardware circuits. The junior programmer actively participates in the testing of vehicle electronic systems, assists in setting up test benches, and monitors equipment performance after modifications are implemented. He possesses foundational knowledge of circuit design, microcontrollers, communication protocols, and the C and C++ programming languages, and is proficient in using measuring instruments and debuggers. The junior embedded systems programmer works under the supervision of the senior hardware programmer. He receives technical specifications from the senior programmer and coordinates his work with design engineers regarding the placement of electronics within the vehicle, as well as with process engineers regarding the sequence for equipment testing and calibration on the production line.

4.8 Senior web programmer

The senior web programmer is responsible for developing high-tech networking solutions that provide connectivity between the vehicle and external services. He creates software for interaction between the onboard control unit and cloud platforms, navigation services, remote diagnostic servers, and over-the-air (OTA) firmware update systems. His work includes designing the architecture of network modules, configuring data transmission security systems, developing APIs, and integrating the vehicle's electronic components with internet services. He solves the most complex technical challenges, establishes technical requirements, and oversees the correct implementation of the vehicle’s network functions. The senior web programmer interacts with the director, who defines the functional requirements, as well as with hardware programmers and design engineers to ensure the compatibility of electronics and software.

4.9 Junior web programmer

The junior web programmer is responsible for the development and support of the factory's internet resources, including the online store and the official corporate website. He creates web page designs, application interfaces, and visual elements, ensuring a user-friendly experience across the company’s services. Additionally, he handles the installation and configuration of web applications running on the vehicle's onboard microcomputer, prepares user control panels, updates UI elements, and conducts testing. The junior web programmer is accountable for the usability and visual quality of digital services, providing employees and customers with seamless access to necessary functions and information. His work involves executing applied tasks under the guidance of the senior specialist, adjusting visual and programmatic functionality, and adapting web applications to meet factory requirements.

4.10 Assembly specialist

The assembly specialist performs the vehicle assembly within the dedicated assembly area. This stage represents the final operation of the entire production cycle. At a single station, the assembler attaches the frame to the monocoque, sequentially installing components onto the frame and mounting the suspension, transmission elements, electrical wiring, power units, electronic modules, control systems, and auxiliary equipment. All tasks are performed according to the process sheet developed by the process engineer, strictly adhering to the specified sequence and requirements for tightening torques, clearances, and tolerances. Throughout the process, the assembler constantly monitors the precision of component installation and their mutual compatibility. If misalignments, defects, or non-conformities are identified during assembly, he immediately informs the process engineer or design engineer to resolve the issue promptly. This feedback loop allows for rapid adjustments to the design or manufacturing technology, thereby increasing the quality of the final product. The assembler may propose more efficient, faster, or safer methods for part installation, optimizing the sequence of operations and simplifying the assembly process. Such proposals are reviewed by the process engineer and, if necessary, integrated into the production documentation. The assembler possesses high qualifications, attentiveness, precision, and a strong sense of accountability. The reliability, functionality, and quality of the finished vehicle depend directly on his skill. It is at the assembly station where the vehicle takes its final form and becomes ready for operation, making the assembler one of the key figures in the manufacturing process.

4.11 Machine operator

The machine operator is a highly skilled specialist who manufactures parts in the machining area. He possesses deep knowledge of mechanical engineering, is proficient in reading blueprints, and works with CNC (Computer Numerical Control) programs. His professionalism directly determines the precision of components, the reliability of assemblies, and the overall quality of the vehicles produced by the factory. His work focuses on CNC machines, lathes, milling machines, and additive manufacturing equipment. Using digital models in accordance with engineering documentation and process maps, the machinist produces parts from raw workpieces. On CNC machines, he performs precision surface machining, drilling, milling, and turning operations. On lathes, he manufactures hubs, drive shafts, and steering components, while milling machines are used for gears and gear racks. In the additive manufacturing section, the machinist uses a 3D printer to produce suspension knuckles, electric motor housings, and gearbox housings. After processing, the machinist cleans the part surfaces, removes burrs, and performs dimensional inspection—checking sizes and the geometry of mating surfaces using measuring instruments. He transfers finished parts to the assembly area, ensuring the continuity of the production process. The machinist is also responsible for monitoring the technical condition of the equipment. Since machines require constant observation, setup, and timely maintenance, he is capable of detecting malfunctions at an early stage, replacing worn elements, and preventing emergency situations. During the work process, the machinist identifies machining defects and suggests ways to rectify them. If necessary, he may propose changes to the manufacturing technology if it improves part quality or reduces production time.

4.12 Welder

The welder performs the welding of metal structures at a specialized welding station. The strength, geometry, and safety of the vehicle's structural elements depend directly on his work. The profession requires high qualifications, precision, physical endurance, and strict adherence to technological standards. The primary task of the welder is the fabrication and assembly of metal units and structures. He performs the welding of the vehicle frame and suspension arms, which are made of aluminum alloy. The welding is carried out using semi-automatic electric arc welding in a shielding gas environment (MIG), which ensures high-quality seams, minimal part distortion, and reliable structural joints. Before starting the process, the welder secures the frame components on a welding jig (fixture), locking them in the design position to maintain precise geometry and prevent warping. Once fixed, he sequentially welds the joints while monitoring welding parameters, depth of penetration, and the visual appearance of the weld bead. The welder's work involves stringent safety requirements. He wears a specialized protective uniform, a welding helmet, and personal respiratory protection. Since hazardous fumes are released during welding, the station is equipped with auxiliary exhaust ventilation, and the welder uses a mask with a built-in respirator function. Upon completion, the welder cleans the seams, removes spatters or overlaps, and prepares the surface for subsequent operations. Depending on the production route, the finished welded structures are transferred either to the painting section for anti-corrosion protection or directly to the assembly area.

4.13 Electrician

The electrician is responsible for the assembly, installation, and testing of all electrical and electronic systems in the vehicle. Their work covers everything from individual electronic nodes to complex electrical circuits that provide power, control, and safety for the vehicle. The electrician performs the installation of electrical circuits, cable routing, and the mounting of connectors, fuses, and switching elements. They assemble control units, motor speed controllers, battery packs, and distribution hubs. When assembling battery packs, the electrician connects individual cells into modules, installs control and protection systems, and verifies proper cell balancing and contact reliability. When working with the motor speed controller, the electrician mounts power and signal circuits, configures operating parameters, and prepares the device for further testing. Special attention is paid to insulation quality, correct wire labeling, and protecting electrical connections from vibrations and external influences. After installation, the electrician conducts a series of tests: measuring resistance, checking for short circuits, and verifying the performance of nodes under load. If a malfunction is detected, they identify the cause, rectify the defect, and, if necessary, report the issue to the process engineer or designer. All operations are carried out in accordance with electrical schematics and technical documentation. The reliability of the vehicle's electronic systems, its operational safety, and the stable performance of all electrical components depend directly on the electrician's expertise.

4.14 Molder

The molder manufactures parts and assemblies from composite materials used in the vehicle's construction. Their work involves high-tech molding processes that require precision, meticulousness, and a deep understanding of material properties. The molder prepares the molds, cleans them, and applies mold release agents before laying up layers of prepreg in accordance with the process sheet. He carefully monitors fiber orientation, the number of layers, proper placement, and the uniformity of the mold filling. Additionally, the molder carries out the vacuum bagging process: he places the component into the mold, seals the vacuum bag, connects the vacuum system, and monitors pressure, temperature, and dwell time during the curing cycle. He ensures that the finished product is free of voids (air pockets), wrinkles, fiber displacement, or other defects that could compromise the strength and quality of the part. The molder interacts with the senior process engineer to receive process sheets, instructions, and molding cycle parameters. He coordinates with design engineers to clarify part features, dimensional requirements, and tolerances. After manufacturing, the molder performs a visual quality inspection, prepares the product for further processing, and transfers it to the machining area or the paint booth.

4.15 Painter

The painter works in a specially equipped paint booth featuring ventilation, filters, a drying system, explosion-proof lighting, and temperature control. The painter utilizes professional equipment, including spray guns, orbital sanders, pneumatic lines, filters, and specialized respirators. The painter’s workspace includes not only the booth itself but also the paint complex equipment hall, where filters, hoses, protective clothing, and tools are stored. The painter uses specialized coveralls, gloves, masks, and respiratory protection systems. His tasks include sanding components, removing defects, degreasing surfaces, applying primer, painting, ensuring anti-corrosion protection, and inspecting the final coating. The painter combines professional craftsmanship with an artistic sense and technical precision. He possesses high concentration, meticulousness, and a deep knowledge of coating application technologies. The painter strictly adheres to safety regulations, as his work involves solvents, aerosols, and heated air in proximity to electrical equipment. The vehicle's aesthetics, the evenness of the finish, the absence of defects, and the durability of the paint layer all depend on his expertise. The painter receives components for painting from the assembly or fabrication units and returns the finished, coated parts to the assembly stage. He interacts with the process engineer, who determines the coating application modes, the sequence of operations, and quality requirements—especially when changing colors, selecting new materials, or resolving surface quality issues.

4.16 Facilities & domestic assistant

The factory's domestic staff member is responsible for maintaining cleanliness and order throughout the entire enterprise. Her work covers both administrative offices and production areas. Daily, she ensures the conditions in which employees can perform their work safely and effectively. Her range of tasks includes cleaning the offices, the engineering hall, the locker room, the entryway, the dining room, and utility spaces. She is responsible for mopping floors, wiping down surfaces, dusting equipment, and maintaining hygiene in the restrooms. In the kitchen, the domestic worker prepares lunch for the staff, portioning the meals into containers and placing them in the refrigerator; employees then take their lunch and reheat it in the microwave. She also handles the dishwashing and ensures the kitchen remains orderly. In the production shop and the engineering hall, she sweeps the floors, collects small debris, and disposes of waste. A transparent plastic jar is kept in the workshop, where she places any small items found on the floor (bolts, nuts, washers, paperclips). This simple yet highly practical solution allows workers to quickly retrieve misplaced parts and prevents them from being lost or sucked into the machinery. On the factory's surrounding grounds, she trims the living hedge and clears litter. Her meticulousness and attention to detail make her an indispensable part of the team, providing the factory with impeccable domestic maintenance.

Conclusion

This book has consistently described a mini-factory for the small-scale production of electric vehicles. The facility presented here can be viewed as a foundation for future development, the implementation of new technologies, and the refinement of industrial processes. The principles and solutions described can be adapted for other enterprises, educational projects, and engineering developments. In this sense, the book describes a completed object, examining all components of the enterprise. This perspective allows one to see the factory as a single mechanism, where every part influences the final result. This factory has become the company's first step—a testing ground for perfecting technologies. Particular attention has been paid to the logic of the manufacturing process, built on a step-by-step principle: from parts fabrication to vehicle assembly at a single station. Such an organization exemplifies small-scale production, where flexibility, quality control, and close interaction between employees are of decisive importance. The described solutions demonstrate how, even on a limited scale, it is possible to create an efficient, modern, and safe production environment. The factory is a complex, multifaceted mechanism driven by people. The role of the human element is paramount to its operation. Sixteen professionals, each an indispensable link in a single chain. From the strategic decisions in the director’s office to the painter’s keen eye and the domestic worker’s diligent care—it is this human contribution that transforms a set of blueprints and materials into a finished, high-tech vehicle. Despite the high level of technology, automation, and modern equipment, it is the specialists who form the enterprise's resilience, its culture, and the quality of its products. Their accountability, professionalism, and synergy determine the success of the entire undertaking. The Dubina mini-factory proves that modern automotive manufacturing does not necessarily require gargantuan assembly lines and thousands of employees; on a small footprint, with the help of sixteen people, it was possible to create a closed-loop vehicle production cycle. The Dubina mini-factory stands for flexible production and a cohesive team striving for perfection in every detail.