Intelligent Goose Nest: Review, Development and Evaluation of Initial Results for Design Concepts

Yuhao Cheng, Haifeng Duan, Rani Schilling, Maryna Popova and Stefan Twieg
Department of Electrical, Mechanical and Industrial Engineering, HS Anhalt, Bernburger Str. 55, 06366 Köthen, Germany
{*yuhao.cheng, haifeng.duan, rani.schilling, maryna.popova, stefan.twieg*}*@hs-anhalt.de*

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Abstract: This work presents the conception and prototyping of a modular goose nest system intended as a first step towards an intelligent, sensor-based nesting environment. Motivated by the lack of suitable laying sites in deep-litter and raised-floor systems, the study focuses on the mechanical design of nest frames, entrance mechanisms, floor geometries and passive egg-collection elements and evaluates their acceptance under farm conditions. Two wooden frame prototypes with different door and floor configurations were constructed and tested with a small group of geese. Nest use and laying behaviour were monitored continuously via video and analysed through manual event annotation (approach, entry, exit, egg laying, and interactions with structural elements). The experimental results show that, although the frame construction and basic floor concepts are mechanically robust and suitable for barn environments, the tested entrance mechanisms substantially reduced nest acceptance. Across all phases, only 1 of 40 eggs was laid in the nest, and none were successfully transported to the collection tray. Video analysis linked this low use primarily to aversive features of the side-hinged door with magnetic stop (noise, partial closing, transient trapping) as well as to strong group-nesting tendencies at floor-laid eggs outside the nest. Rather than demonstrating a ready-to-use solution, the present study identifies critical design constraints and behavioural failure modes that must be addressed in subsequent development stages. The findings highlight the need for quieter, low-resistance and low-risk entrance designs, mechanically robust yet chew-resistant materials, and management strategies that prevent the formation of external group nests. These lessons provide a concrete basis for the next generation of intelligent goose nests and for more targeted experimental evaluation of integrated sensor systems.

1 INTRODUCTION

Conventional goose husbandry presents numerous challenges, particularly in terms of monitoring egg-laying, ensuring hygienic conditions, and maintaining animal welfare [1]. Traditional goose husbandry systems, such as deep-litter systems, offer hygienic advantages as excrement and excess water fall directly into a pit or onto the floor beneath. However, such systems often lack suitable, species-appropriate nesting environments, leading to increased instances of floor eggs [2][3]. As [4] highlights, these systems struggle to provide optimal conditions for egg-laying. Social and reproductive behaviors, including group nesting tendencies, further complicate these issues and impact nest acceptance. These behaviors, along with the natural tendencies of geese to form external group nests, are crucial factors in the design and evaluation of artificial nesting systems [5]. One commonly applied method for identifying individual laying geese is trap nesting, which allows targeted selection and culling. Typically, this involves installing a mechanical door on a standard nest box that closes once the goose enters, preventing escape until manually released. While effective under controlled conditions, this method proves unreliable when geese lay eggs in alternative locations, especially in deep-litter systems, where multiple potential nesting sites complicate individual egg attribution [3].

An alternative approach involves manually inspecting geese in the evening to detect those ready to lay. Identified individuals are then placed in separate nesting compartments equipped with locking doors. This labor-intensive process is usually conducted four to seven days per week. Egg counts are then estimated proportionally. In more intensive systems, raised flooring is employed to optimize space and reduce bedding requirements. Commonly used materials include wooden slats or expanded metal/plastic grids. These setups offer hygienic advantages, as excrement and excess water fall directly into a pit or onto the floor beneath. However, while efficient in terms of space and maintenance, such systems often lack suitable, species-appropriate nesting environments, as [6] describe, making them less ideal for natural egg-laying behavior.

To address these shortcomings, the present study focuses on the development of a structurally optimized, modular, and automatable goose nest that facilitates secure, species-appropriate egg-laying while enhancing monitoring and collection processes.

Figure 1 illustrates the overall operational workflow of the intelligent nest system; from the moment a goose enters the nest to the final storage of processed event data. The sequence begins with controlled nest access through the mechanical entry system, followed by detection of the animal's presence through load cell measurements. Once inside, the goose is identified via RFID, enabling individual attribution of subsequent events. A characteristic pattern in the weight signal indicates the laying of an egg, which triggers the recording of relevant sensor data. These data are then evaluated algorithmically to link the detected egg to the identified animal. After validation, the egg is marked with its corresponding identifier, and all information is transferred to the database for long term storage and later analysis. The diagram highlights the coordinated interaction between mechanical elements, sensor systems, microcontrollers, and backend infrastructure, illustrating how local detection and global data processing together form the foundation of the intelligent nest system.

This paper reports on the first project phase, which focuses on the conception, construction and behavioural evaluation of mechanical nest prototypes, including frame, entrance mechanisms, floor designs and egg collection elements. The electronic architecture shown in Figures 1 and 2 has been implemented at the prototype level but is not yet evaluated experimentally in this work. A subsequent project phase will systematically assess the performance of the load cell subsystem, the RFID based identification, the database backend and the connected output devices under farm conditions.

2 GOOSE ELECTRONIC AND MECHANIC SYSTEM DESIGN

2.1 Electronic System Design

Figure 2 illustrates the system architecture underlying the intelligent nest prototype, highlighting the interaction between local sensing components and the external processing infrastructure. Inside the nest, the RFID reader and the load cell module collect identification and weight data, which are transmitted to a central database computer for event reconstruction, validation, and storage. Based on the processed information, the system triggers two peripheral units located outside the nest: an automated marking device that applies a unique identifier to each egg, and a user display that presents real-time information such as the laying sequence or animal-specific events.

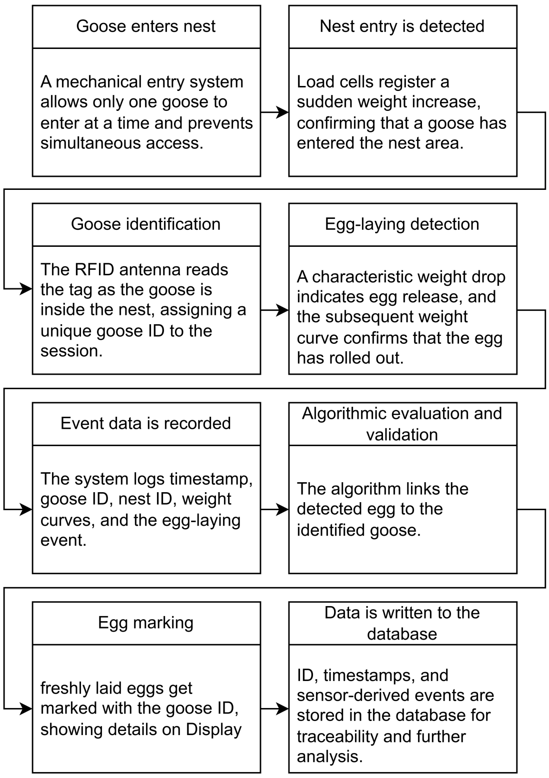

Figure 1: Overview of the functional workflow of the intelligent nest system, illustrating the sequence from controlled nest entry and sensor-based event detection to animal identification, egg attribution, marking, and database integration.

This architecture separates environmental sensing inside the nest from computational tasks and actuator control outside, allowing robust operation in barn conditions while ensuring reliable communication and data flow across all system components. In the present project phase, this electronic architecture is defined conceptually and serves as the target framework for later integration. The practical work reported in this paper therefore focuses on the design and behavioural evaluation of the key mechanical components that support the electronic system, namely the nest frame, entrance doors and ramp, floor geometries and passive egg collection paths. The detailed implementation and experimental testing of the electronic subsystems (load cell and RFID units, microcontroller modules, communication links and backend processing) will follow in subsequent project phases, building on the mechanical baseline established in this study.

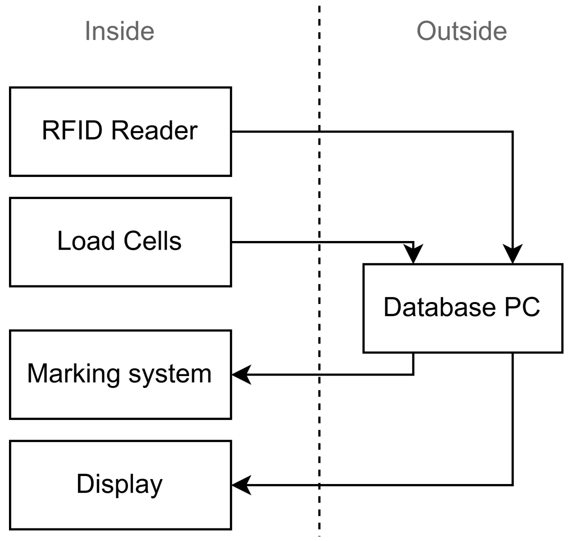

Figure 2: System architecture of the intelligent nest prototype, showing internal sensing components (RFID reader and load cells) and external processing units (database PC, marking system, and display) interconnected through bidirectional communication.

2.2 Frame Design

The primary objective of the frame design is to create a safe, comfortable, and functional environment for egg-laying. The nest must allow geese to enter and exit freely while preventing multiple geese from occupying the same nest simultaneously, thereby reducing stress and disturbances during egg-laying. Additionally, the frame should accommodate sensors, such as load cells, for monitoring purposes. As [7] points out, lightweight construction principles are key in ensuring both stability and ease of manufacturing. Therefore, both wooden and aluminum frame variants were designed with a two-level structure: the upper section serves as the nesting area, while the lower section houses technical components.

Where possible, the use of electrical components was avoided to minimize system complexity, eliminate the need for wiring, and facilitate thorough cleaning. The frame must also withstand high humidity, dust, and frequent exposure to water and detergents [6]. Structural integrity and long-term material durability were thus key design criteria.

2.2.1 Wooden Frame Design

The first frame design is constructed from wood and consists of two side walls, a rear wall, and two front walls, as illustrated in Figure 3.

Figure 3: Wooden frame design.

The walls are connected using wooden battens, with four along the bottom and two at the top, to ensure structural integrity. Since the material is wood, the walls are fastened using self-tapping screws to provide a stable and durable connection. Additionally, a handle and a window are integrated into one of the side walls. A horizontal batten at the top adds further structural stability.

2.2.2 Aluminum Profile Frame Design

The aluminum frame is constructed from aluminum profiles cut to various lengths and assembled into a stable structure. The individual profiles are joined using screws to ensure structural robustness (see Fig. 4).

The wooden frame is the preferred option due to its simplicity, ease of construction, and integration of practical features like a handle and window for accessibility. It provides sufficient structural integrity using battens and screws, aligns well to minimize system complexity, and allows easier customization or adjustments during use.

2.3 Entrance Mechanism Design

2.3.1 Gravity-Activated Mechanism (Option 1)

The developed entrance system features an automatic door mechanism based on a combination of gravitational force, leverage, and a two-part flap door. Before entry, the door remains open. When a goose steps onto the inclined, pivot-mounted floor, the resulting downward motion activates a mechanism that automatically closes the door.

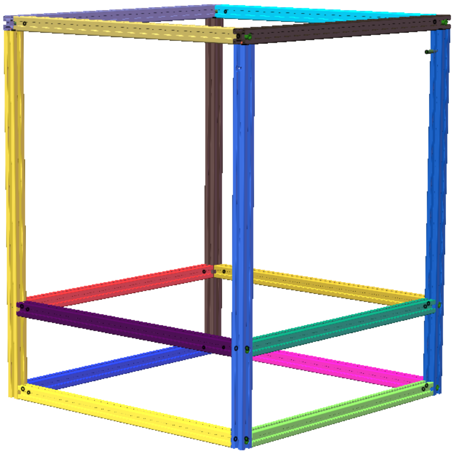

Figure 4: Aluminum profile frame design.

To ensure that the goose inside the nest can exit while preventing additional geese from entering, a split-door design with a restricted hinge angle is used. This construction allows the door to open only outward from the inside. A torsion spring returns the door to its initial position after the goose exits, enabling con-tinuous operation. The floor is pivotally mounted at a fixed point on the frame, while the door is attached via a rotary joint. The mechanical linkage between floor and door is currently under development; a linkage rod system is being considered as a potential transmission mechanism.

2.3.2 Gravity-Activated Mechanism (Option 2)

To improve weight-measurement accuracy, the nest floor in Option 2 was designed as a vertically movable platform that remains level at all times, independent of the door position. This configuration not only enhances measurement fidelity but also provides a more stable and comfortable surface for the geese, particularly during egg laying.

The door movement and floor motion are mechanically coupled through a guided linkage system. The lower linkage rods are mounted on rails integrated into the frame, allowing both controlled vertical displacement of the floor and coordinated motion of the door. The overall kinematic concept is illustrated in Figure 5, which shows the complete 3D model of the entrance mechanism.

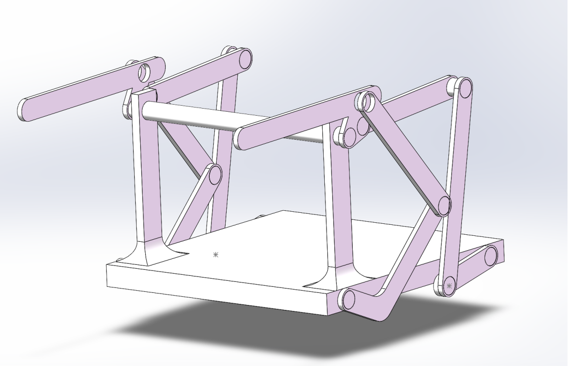

Figure 5: 3D model of the gravity-activated entrance mechanism (Option 2).

2.3.3 Top-Hinged Mechanism

The design attaches the door to the frame using a rotational axis or a hinge, allowing it to rotate freely. The door can be mounted directly on the axis or hinge, or connected via a connector to facilitate easy replacement. By appropriately determining the center of gravity, the door remains at rest with the short side pointing downward and the long side open. As shown in Figure 6, a schematic representation of the door in its open and closed positions is provided.

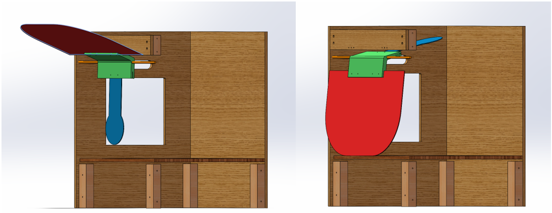

Figure 6: 3D model of the top-hinged door mechanism: opened (left) and closed (right).

2.3.4 Side-Hinged Mechanism

As shown in Figure 7, the side-hinged door mechanism is laterally mounted to the frame via a hinge or rotational axis. Two connected door panels form a right-angled door structure functioning as a single unit.

This design allows the inner door to open when a goose enters the nest, while the outer door automatically closes as a result of the connected geometry. Additionally, magnets are incorporated to hold the door in place when the opening angle is insufficient, ensuring that the door either remains open or closes automatically depending on its position. This construction not only simplifies the entry and exit process for the geese but also effectively prevents unintended opening or closing of the door, thus enhancing both usability and structural stability.

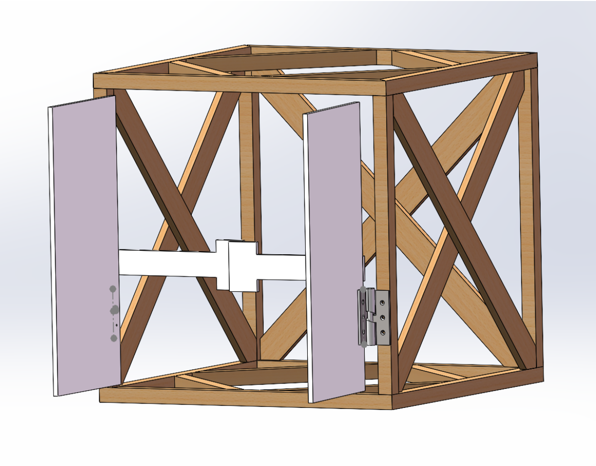

Figure 7: Side-swing door mechanism.

2.3.5 Inclined-Movement Floor Module

The inclined-movement floor module integrates the entrance control directly into the floor structure using a pivot-mounted plate (Fig. 8). When a goose steps onto the plate, it initially remains horizontal. As the animal moves forward and crosses the pivot axis, the rear part of the plate lowers to form a shallow ramp, while the front part rises and blocks the entrance. This automatic transition prevents additional geese from entering once the nest is occupied. Compared to more complex gravity-activated linkage systems, the hinged mechanisms described earlier (top-hinged and side-hinged doors) provide simpler, more robust and easier-to-maintain solutions. These alternatives therefore remain the preferred options for subsequent prototype stages.

2.4 Nest Floor Design

The floor must provide a stable surface for the geese while enabling reliable passive egg transport. A slight inclination is required to ensure that eggs roll toward the collection area without compromising the animals' mobility or comfort.

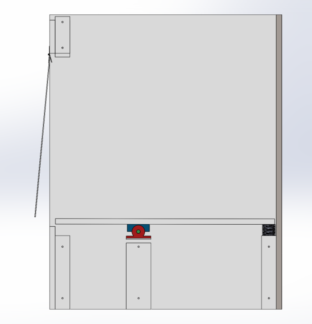

Figure 8: Inclined-movement floor module with pivoting plate.

2.4.1 Rear-Opening Floor Panel

The rear-opening design (Fig. 9) uses a central depression and a gentle rearward incline that guides eggs naturally toward the collection opening. This approach avoids complex bowl-shaped geometries, simplifies manufacturing, and reduces material and tooling requirements. It also supports easy installation and maintenance while ensuring safe and reliable egg flow, making it well suited for large-scale farm environments.

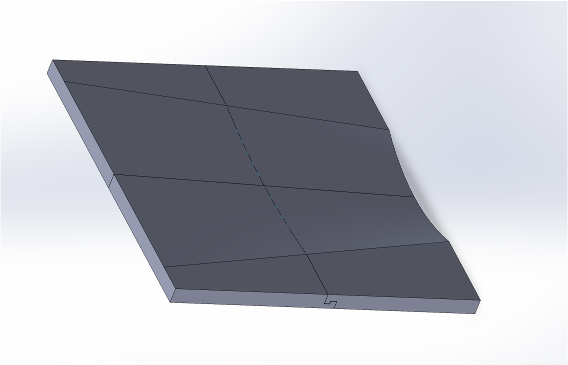

Figure 9: Rear-opening floor panel.

2.4.2 Center-Drain Floor Panel

The center-drain variant (Fig. 10) guides eggs directly through an opening in the floor, reducing the need for side or rear cut-outs. While production is straightforward, the design requires a large opening (130–140 mm) to accommodate goose eggs. This creates a safety risk, as birds may step into the hole and potentially injure themselves, particularly when entering or moving inside the nest.

For these reasons, the rear-opening panel is preferred: it transports eggs effectively without introducing injury hazards and offers simpler construction, lower costs, and improved long-term practicality.

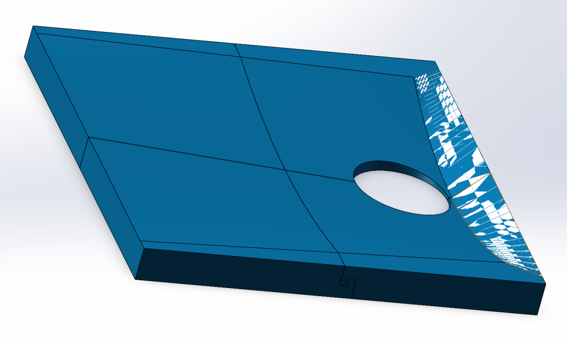

Figure 10: Center-drain floor panel.

2.5 Egg Collection Tray Design

According to the functional requirements, goose eggs should roll down from an elevated position in a row and remain undamaged. As part of the nest space is reserved for technical instruments, the eggs descend from above and eventually reach the egg collection tray. Therefore, a reliable cushioning mechanism must be installed at the end of the tray to prevent damage from impacts or excessive rolling speed. Depending on the floor design, two different rail systems are used. If the egg collection hole is located on the floor, the egg tray can be positioned at the front, underneath the ramp. This configuration saves space and offers a clean solution. Figure 11 shows the front tray layout as a visual representation of this concept.

Although this method is effective, it is less practical for a rear-opening system. If such a design were used, the eggs could fall vertically due to the curvature of the drop pipe, increasing the risk of breakage. Therefore, an alternative design is implemented. This version uses a flatter incline, which is gentler on the eggs. However, the main trade-off is increased space requirements. This solution is illustrated in Figure 12, showing the side-mounted tray configuration.

3 NEST DESIGN SELECTION

3.1 Frame Material Selection

The choice of frame material had to consider corrosion resistance, moisture resistance, low weight, mechanical robustness, and cost-efficiency, as [8] discusses in their work on material properties. Based on these criteria, several materials were compared (see Table 1).

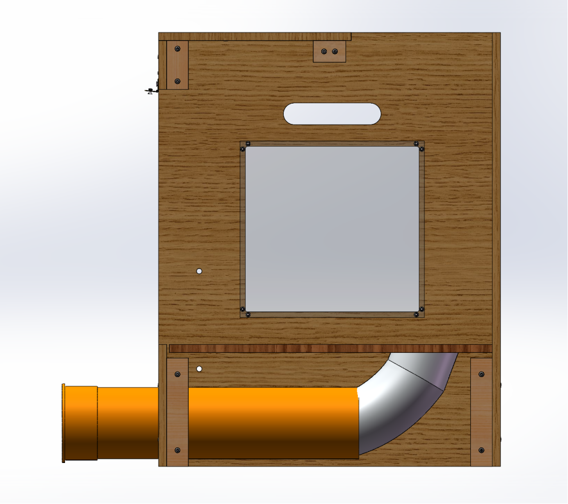

Figure 11: Front egg collection tray.

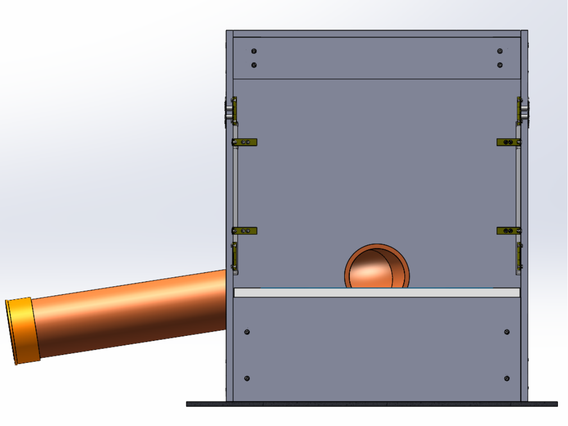

Figure 12: Rear egg collection tray.

Table 1: Comparison of different materials [8], [7].

Material	Corrosion Resistance	Density [g/cm³]	Hardness [HB]	Price [€/kg]
Stainl. Steel	Excellent	7.8	200	16
Al-Alloy	Good	2.7	60–150	20–30
Wood	Poor	0.4–0.9	70	0.5–1
Iron	Poor	7.8	80–100	0.5–1

For the initial design of the goose nest frame, aluminum profiles were modeled to allow for rapid structural assessment. Due to the high cost, the final material choice was laminated wood panels. This material offers a good balance of stability, ease of processing, environmental friendliness, and cost-effectiveness. Compared to steel, it is lighter; compared to plastics, it is more durable and mechanically stronger. With appropriate moisture protection treatment, the frame structure remains stable and durable even in humid and dusty environments.

3.2 Entrance Mechanism Selection

Following a comparative analysis of various entry mechanisms and considering the design requirements, two mechanisms were selected: a top-hinged door and a side-hinged door. More complex solutions, such as a bottom-door linkage mechanism or a side door with a diagonally movable floor module, were rejected due to their structural complexity, implementation challenges, and cleaning difficulties. In contrast, the top-hinged and side-hinged doors offer a simple, robust design based on basic mechanical principles. They ensure reliable functionality, enable cost-effective manufacturing and easy cleaning, and thus meet the practical requirements of a functional goose nest.

3.3 Floor and Egg Collection Method Selection

Following the selection of the top-hinged and side-hinged doors, suitable floor and egg collection systems were defined to ensure unobstructed access and reliable passive egg transport. Nest 1, equipped with a top-hinged door, uses a rear-opening floor panel that guides eggs from a shallow central depression directly into a subfloor collection tube. This enables rapid egg removal and reduces the risk of breakage or pecking. Nest 2, featuring a side-hinged door, employs a floor panel that directs eggs through an opening in the rear wall onto a gently sloped collection surface. This maintains free movement for the geese while ensuring a short and safe rolling path. Both systems rely solely on passive mechanical elements. By avoiding electronics in the collection area, they remain robust against moisture and contamination, reduce maintenance requirements and provide long-term operational reliability under barn conditions.

4 MANUFACTURING

4.1 Frame Construction

The frame is constructed from multilayer plywood for its strength and stability. Fastening is achieved using wood screws and reinforcing wooden battens. L-shaped metal brackets are added to all corners to enhance impact resistance and prevent deformation caused by goose activity.

Before assembly, panels are precisely cut into structural parts: two side walls, one rear, and one front wall. Edges are sanded to avoid injury. Window outlines are marked and 4 mm relief holes are drilled at each corner to prevent cracks. The window opening is then cut and sanded. An acrylic pane is mounted using adhesive and corner screws.

For the handle, two 20 mm holes are drilled and connected with a jigsaw cut; all edges are smoothed. Panels are laid flat pre-assembly for alignment. Vertical accuracy is ensured with a square, and battens are mounted flush to the side walls. The finished structure is impact-tested, confirming material strength and stability under typical goose movements.

After the frame was completed, several functional tests were conducted to evaluate the practical suitability of the designed goose nest. First, a load test was performed to ensure that the structure could withstand the weight of the geese and their movements. This was followed by a mechanical safety test, specifically checking for sharp edges and potential injury risks for both the animals and personnel during assembly, disassembly, or cleaning. A stability test was carried out to assess resistance to vibrations or sudden shocks. Additionally, the corrosion resistance of the materials used was examined to ensure long-term durability in a humid barn environment. Finally, a light transmission test was conducted to verify whether the transparent or semi-transparent side walls allow sufficient light into the nest without permitting direct sunlight.

4.2 Nest 1

4.2.1 Top-hinged Door Mechanism with Servo Motor

Nest 1 includes a top-hinged door with a motor-operated locking bolt, as seen in Figure 13. A servo motor is installed 375 mm above the ground on the right frame side. When weight is detected by load cells, the motor rotates the locking bolt 90°, preventing the door from opening inward. This ensures only one goose enters at a time. The motor cable runs externally along the frame and beneath the nest floor to avoid goose interference.

4.2.2 Egg Collection Area

This nest features a rear floor opening for egg collection. A 126 mm diameter hole is cut for the collection tube, considering tolerance. A 50 mm-thick extruded polystyrene (XPS) foam plate is added, angled toward the opening to guide eggs smoothly into the tube. A flexible pipe runs under the floor, through the rear panel, and extends beneath the ramp for safe egg transfer.

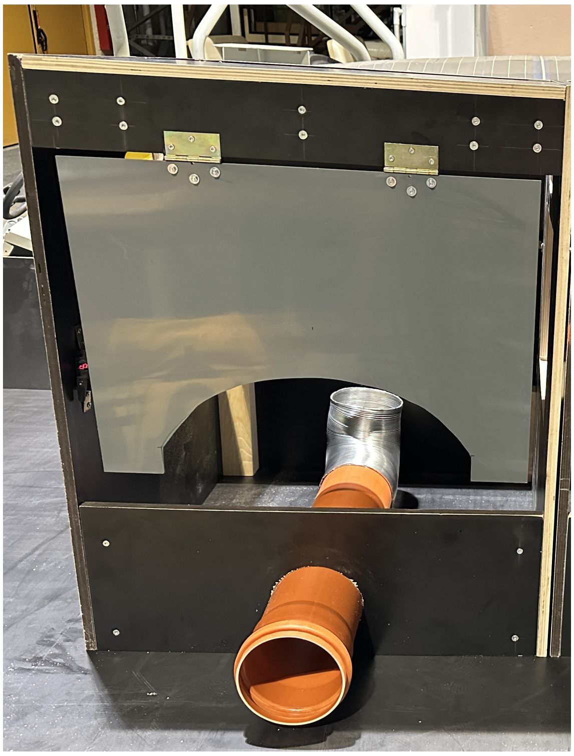

Figure 13: Configuration of Nest 1 with top-hinged door and center-drain floor panel.

4.3 Nest 2

4.3.1 Side-hinged Door Mechanism

Nest 2 uses a side-hinged door system. Panels are cut to shape, and each side includes an outer and inner door. The outer doors are attached to the frame; inner doors are mounted onto them using 90° metal brackets, as illustrated in Figure 14.

Magnetic stops are added to control door positioning (see Fig. 15). When a goose pushes the inner door, it swings inward and is held open by the magnet, while the outer door remains closed to prevent escape or unintended entry.

Figure 14: Configuration of Nest 2 with side-hinged door and rear-opening floor panel.

Figure 15: Magnetic stops of the side-hinged door mechanism.

4.3.2 Egg Collection Area

A 126 mm opening is cut into the rear wall for the egg collection pipe. Two floor panels angled at 110° direct eggs into the pipe, which is supported and aligned by two stabilizing struts. A 50 mm XPS foam layer is added, sloping toward the rear opening to ensure eggs roll efficiently.

4.4 Electrical Component Integration

The load cell is mounted on the underside of the wooden platform, with force transmission established through a beam beneath the floor. Screw holes are countersunk to avoid protrusions and ensure a flush surface. The installation of the load cells and the supporting structure is shown in Figure 16.

In addition to weight measurement, the system incorporates an RFID unit for individual animal identification at nest entry. The RFID reader, antenna and microcontroller are housed together in a dedicated electronics module, which is also shown in Figure 16. The load cell subsystem and the RFID subsystem operate on separate ESP32 microcontrollers, enabling independent acquisition, filtering and timing of their respective data streams. Data exchange between the microcontrollers and the database computer is carried out via MQTT. Each controller publishes its data to dedicated topics, allowing the server to merge information into coherent event structures, associate egg-laying events with individual animals, and communicate with peripheral devices such as the display and automated marking system.

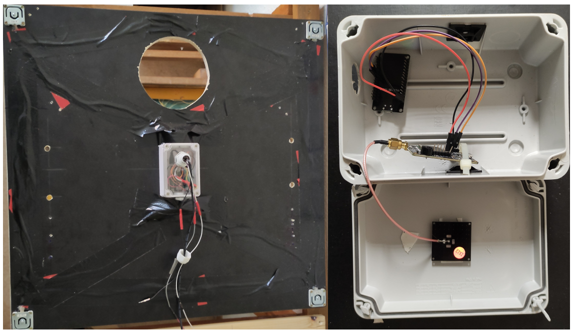

Figure 16: Electronic subsystems of the intelligent nest: load cell assembly beneath the nest floor (left) and RFID module with reader, antenna and ESP32 microcontroller (right).

4.5 Ramp Design

The ramp (see Fig. 17) is 550 mm long and set at an angle of approximately 24.15°, within the recommended range of 20°–25° for goose accessibility. Crosswise anti-slip wooden slats are mounted 50–70 mm apart to enhance traction. The ramp attaches to the nest frame with two hooks for easy assembly and disassembly.

4.6 Experimental Setup and Behavioral Observation

All behavioural tests were carried out in a stable housing with a group of five female geese under routine husbandry conditions. To obtain a precise ground-truth reference for nest use and laying activity, the area in front of the prototype nest and the nest interior were continuously monitored with a fixed video camera operating 24/7 throughout the entire experimental period. The video material was subsequently reviewed and annotated manually. For each goose, all relevant behavioural events were extracted with time stamps and assigned to one of two spatial categories: (i) presence in front of the nest, defined as standing or staying within the approach zone directly in front of the entrance, and (ii) presence inside the nest, defined as all periods during which the animal had fully entered the nest chamber. In addition, each entry and exit event was marked explicitly to reconstruct the exact sequence and duration of visits.

Egg-laying events were identified in the recordings based on characteristic posture changes and the subsequent appearance and position of the egg. For every egg, the approximate time of laying and its final location (inside the nest, rolled to the tray, or outside the nest) were documented. Furthermore, the videos were used to characterise how individual geese interacted with the different entrance mechanisms, including behaviours such as pecking at the door, looking into the nest without entering, hesitating in the approach zone, pushing under partially opened flaps, or reacting to mechanical noises (e.g. the snapping of magnets).

The manually annotated events formed the basis for calculating the cumulative presence times in front of and inside the nest for each goose and experimental phase (Table 2). They also provided qualitative context for interpreting acceptance or avoidance of specific entrance designs and for linking observed behaviours to the mechanical properties of the prototype nests.

5 RESULTS

All tests were conducted in a stable housing with a group of five female geese. Prior to these tests, the general Nest Frame design was evaluated for safety and acceptance. Nest 1, which used a Center-Drain Floor Panel, posed a potential risk of injury, as the geese repeatedly stepped directly onto the drain. For this reason, Nest 1 was not tested further. The experiments therefore focused on Nest 2, equipped with a side-hinged entrance supported by magnets. In that configuration, several issues became apparent: in some cases, geese triggered only one of the two doors, leaving the other flap closed, or pushed themselves underneath the door without activating the mechanism, as seen in Figure 17. In addition, the snapping noise of the magnets startled some animals and led to reluctance to enter. The Inclined-Movement Floor Module, tested separately as a simple passageway, was accepted without hesitation, with all geese passing over it without observable stress.

Figure 17: Goose only activates one door of the side-hinged entrance mechanism.

Three consecutive experimental phases were implemented to assess acceptance, access behavior, and laying activity as a function of the entrance mechanism: Phase I (24–28 Jan, nest with door including magnetic stop), Phase II (28–31 Jan, nest with door but without magnets), and Phase III (31 Jan–13 Feb, nest body without any entrance mechanism). The quantitative outcomes are summarized in Table 2, which lists for each goose the cumulative time spent in front of the nest and the time spent inside the nest.

Table 2: Cumulative presence times [min:s] in front of and inside the nest across phases.

	Phase I		**Phase II**		**Phase III**	
Goose	Front	Nest	Front	Nest	Front	Nest
G1	03:38	00:00	15:44	00:00	18:42	34:31
G2	00:00	00:00	00:06	20:46	47:33	87:09
G3	03:44	00:00	06:00	05:16	125:32	77:22
G4	01:49	04:19	04:59	62:26	35:14	20:38
G6	04:55	00:00	03:20	00:00	13:24	30:35
Total	**14:06**	**04:19**	**30:09**	**89:28**	**240:25**	**250:15**

In Phase I (door with magnets), only Goose 4 entered the nest, with a total of six short visits amounting to 04:19 min inside. All other animals remained exclusively in front of the entrance without crossing into the nest chamber. The cumulative time spent in front of the nest was low (14:06 min).

During Phase II (door without magnets), a marked increase in nest use was observed. Goose 3 entered the nest twice (05:16 min in total), Goose 2 entered six times (20:46 min), and Goose 4 entered twelve times, reaching the maximum cumulative presence of 62:26 min inside. In contrast, Goose 1 and Goose 6 only remained in front of the entrance without entering. Overall, the cumulative time spent inside rose to 89:28 min, while the total front times more than doubled (30:09 min).

In Phase III (nest body without entrance mechanism), nest use broadened further: all geese entered the nest at least occasionally. Goose 2 accumulated the longest presence (87:09 min across 13 visits), followed by Goose 3 (77:22 min across 21 visits). Goose 1 and Goose 6 showed moderate use (34:31 min across 8 visits and 30:35 min across 7 visits, respectively), while Goose 4 reduced her nest presence to only 20:38 min across 9 visits. In absolute terms, the total front-of-nest time reached its maximum (240:25 min), and the cumulative inside-nest time also peaked at 250:15 min. When normalized by phase length, the average daily presence in front of the nest continued to increase across all phases, whereas the average daily time inside the nest was highest in Phase II and then declined in Phase III, although it remained well above Phase I. This suggests that while approach activity kept rising with prolonged exposure to the structure, the actual time spent inside was most pronounced once the magnets were removed but before the entrance mechanism was fully eliminated.

Beyond the quantitative presence times, the manual video annotations revealed several recurring behavioural patterns across all five geese that are directly relevant for the evaluation of the nest prototypes. First, the entrance proved to be a critical interaction point: all animals were repeatedly observed approaching the nest, inspecting the doorway visually, and withdrawing again without entering. This pattern occurred across all phases and independently of individual differences, indicating that the design and kinematic and mechanical characteristics of the entrance system strongly influence initial acceptance. A second consistent observation concerned the interaction between the geese and the mechanical door elements. In all individuals, at least one event was recorded in which the animal's back or feathers came into contact with a moving or partially closing door wing, and in several cases minor trapping between door components occurred. Such incidents did not result in injury but created brief interruptions in movement, and in at least one individual, subsequent hesitation when passing the doorway. These findings support the quantitative results that the side-hinged construction and the magnetic stop introduced mechanical constraints that reduced acceptance and, in some cases, generated aversive experiences. Across all recordings, the geese also showed pronounced manipulative behaviour directed at structural nest components. The floor mat, ramp surface, and frame edges were frequently pecked, lifted, or chewed, sometimes causing visible damage such as fraying or detachment of adhesive tape. These behaviours indicate that exposed surfaces in the nest vicinity are not only passive load-bearing structures but are actively used as exploration and pecking substrates, which has direct implications for material durability and safety. Finally, the few eggs laid inside the nest were often not automatically transported out of the nest despite the inclined floor design. Video recordings showed that geese manipulated these eggs using their beak or body and occasionally remained sitting on them. This natural egg-handling behaviour interferes with passive egg-collection mechanisms and highlights the need to reconcile instinctive nesting behaviour with the technical requirements of automated egg removal.

Taken together, these results show that (i) the magnetic closing mechanism substantially inhibited entry, with only one goose entering briefly, (ii) removing the magnets led to the highest daily presence inside the nest, with frequent entries by several animals, and (iii) once the entrance was fully removed, approach activity in front of the nest continued to increase, but the actual time inside decreased compared to Phase II and became distributed across all individuals, with Goose 2 and Goose 3 accounting for the largest shares. This pattern suggests that social hierarchy and individual experiences influenced nest use: for example, Goose 4 became caught with her back at the entrance during Phase II, which likely created a negative association and explains her reduced use of the nest in Phase III. Furthermore, once an egg had been deposited outside the nest, subsequent eggs were repeatedly laid at the same spot. This reflects the natural tendency of geese to form group nests and add their eggs to existing clutches, which has been observed in studies showing that geese cluster and select nest sites together before laying begins [9]. Such behavior underscores a key challenge for nest acceptance: if mislaid eggs remain accessible, they can attract further laying and reduce the motivation to use even well-designed technical nest structures. Preventing the establishment of external group nests is therefore crucial for ensuring consistent use of artificial nesting systems.

Across all phases, a total of 40 eggs were recorded as shown in Table 3. Only one egg (2.5%) was deposited inside the nest, which remained in place and not rolled to the tray. By contrast, the vast majority of eggs (97.5%) were laid outside the nest, highlighting that the experimental setup was only rarely used for oviposition.

Table 3: Overall egg-laying outcomes across all phases combined.

	Total eggs	Inside nest	Rolled to tray	Remained in nest	Outside nest
Count	40	1	0	1	39
Percentage	100	2.5	0	2.5	97.5

To visualize behavioral changes, Figure 18 presents the number of nest visits per goose, separated by experimental phase and displayed as grouped, color-coded bars. This format allows direct comparison of visit frequencies across phases within each individual. The data show that visits increased markedly after removal of the magnets (Phase II) and remained elevated in the open configuration without any entrance mechanism (Phase III). In fact, the total number of nest entries was highest in Phase III, indicating that once the barrier was fully removed, geese not only continued to approach but also entered the nest more frequently than in any previous phase. These results underline the deterrent effect of the magnetic stop and the improved acceptance of both the non-magnetic and open nest designs.

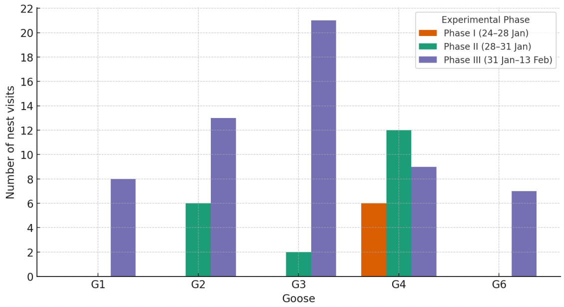

Figure 18: Frequency of nest visits per goose across experimental phases (Phase I–III). Grouped bars indicate the number of visits per individual, color-coded by phase.

6 CONCLUSIONS

This work presented the conception, construction and first behavioural evaluation of modular goose nest prototypes with different entrance mechanisms, floor geometries and passive egg collection concepts. From a purely mechanical perspective, the laminated wood frame and the basic floor and tray designs proved feasible under barn conditions: they can be manufactured with standard materials, withstand typical loads and humidity, and provide a structurally stable basis for integrating sensors and actuators in later project phases.

However, the behavioural results clearly show that the tested entrance mechanisms did not achieve the intended goal of providing an attractive and welfare-friendly laying site. Across all experimental phases, only one out of 40 eggs was deposited inside the nest, and none of the eggs was successfully transported to the collection tray. Manual video annotation linked this low level of use primarily to the side-hinged door system with magnetic stop, which produced sudden snapping noises, partial closing and transient trapping of backs or feathers. These features created aversive experiences for individual geese and likely contributed to the persistent preference for alternative laying sites outside the nest. Once eggs had been laid on the floor, strong group-nesting tendencies further stabilised these undesired locations.

Given the small sample size (five geese) and the short duration of the three experimental phases, the present study cannot provide statistically generalisable estimates of acceptance. Instead, it should be interpreted as an exploratory pilot trial that identifies critical failure modes and design constraints. The findings nevertheless offer several concrete lessons for future development. First, entrance systems must minimise mechanical resistance, impact noise and any risk of transient trapping; this will require redesigned hinges, damping elements and door geometries, as well as quantitative measurements of the forces required to open and close doors. Second, all surfaces in the entrance and nest area must be constructed from robust, chew-resistant materials without exposed adhesive joints, as the floor mat, ramp and frame edges were repeatedly used as pecking and chewing substrates. Third, management strategies are needed to prevent the establishment of external group nests, since accessible mislaid eggs can rapidly override the incentive to use even well-designed technical nests.

Future work should focus on optimizing nest acceptance under farm conditions and on integrating sensor-based monitoring [10] and machine learning [11] to support adaptive management.

In subsequent project phases, these insights will guide the redesign and testing of alternative entrance concepts, followed by a more systematic behavioural evaluation with larger groups, longer observation periods and formal statistical analysis. Only once a reliably accepted mechanical baseline has been achieved will the electronic components described in Section 4.4 and summarised in Figures 1 and 2 be evaluated under farm conditions. In this way, the predominantly negative outcomes of the present study serve as a necessary intermediate step towards a next-generation intelligent goose nest that aligns technical functionality with species-specific behaviour and animal welfare.

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REFERENCES

[1] S. S. Nielsen, J. Alvarez, D. J. Bicout, P. Calistri, E. Canali, J. A. Drewe, B. Garin-Bastuji, J. L. Gonzales Rojas, C. G. Schmidt, M. Herskin, V. Michel, M. Á. Miranda Chueca, B. Padalino, H. C. Roberts, H. Spoolder, K. Stahl, A. Viltrop, C. Winckler, C. Berg, S. Edwards, U. Knierim, A. Riber, A. Salamon, I. Tiemann, C. Fabris, A. Manakidou, O. Mosbach-Schulz, Y. van der Stede, M. Vitali, and A. Velarde, “Welfare of ducks, geese and quail on farm,” EFSA Journal, vol. 21, no. 5, p. e07992, 2023.

[2] D. Campbell, “Floor egg laying: can management investment prevent it?” Journal of Applied Poultry Research, vol. 32, no. 4, p. 100371, 2023.

[3] W. Gu, R. Chang, Q. Xu, W. Zhao, and G. Chen, “Floor eggs in goose breeders: patterns, genetic and environmental influences, and physiological indexes,” Poultry science, vol. 103, no. 3, p. 103450, 2024.

[4] R. Buckland and G. Guy, Eds., Goose production, ser. FAO animal production and health paper. Rome: Food and Agriculture Organization of the United Nations, 2002, vol. 154.

[5] A. Salamon, “The reproductive behaviour of geese and its implications on production and welfare,” World’s Poultry Science Journal, vol. 81, no. 1, pp. 103–116, 2025.

[6] B. Tang, S. Hu, X. Zhang, Q. Ouyang, E. Qing, W. Wang, J. Hu, L. Li, and J. Wang, “Effects and mechanisms of cage versus floor rearing system on goose growth performance and immune status,” Animals : an open access journal from MDPI, vol. 13, no. 16, p. 2682, 2023.

[7] B. Klein, Leichtbau-Konstruktion: Berechnungsgrundlagen und Gestaltung : mit 356 Abbildungen und Tabellen sowie umfangreichen Übungsaufgaben zu allen Kapiteln des Lehrbuchs, 10th ed., ser. Springer Lehrbuch. Wiesbaden: Springer Vieweg, 2013.

[8] W. W. Seidel and F. Hahn, Werkstofftechnik: Werkstoffe - Eigenschaften - Prüfung - Anwendung : mit 389 Bildern sowie zahlreichen Tabellen, Beispielen, Übungen und Testaufgaben, 11th ed., ser. Lernbücher der Technik. München: Hanser, 2018.

[9] Q. Bao, Y. Yao, K. Weng, M. Zheng, Y. Zhang, Y. Zhang, G. Chen, and Q. Xu, “Research note: Comparison on laying behavior and clutch traits among zhedong white geese (anser cygnoides), sichuan white geese (anser cygnoides), and hungarian geese (anser anser),” Poultry science, vol. 101, no. 2, p. 101594, 2022.

[10] I. Omeko, S. Twieg, and M. Obert, “Sensor-based gait analysis : A comparative study of ultrasonic and laser sensors for gait monitoring in rollator-assisted walking,” 2025.

[11] S. Rajanayagam, M. A. Ingrisch, P. Müller, P. Jahn, and S. Twieg, “Enhancing voice activity detection for an elderly-centric self-learning conversational robot partner in noisy environments,” 2025.