

Smartpaw: Design And Development Of A Climate-Responsive Smart Animal Shelter With Automated Emergency Door Activation For Flood And Heat Stress Mitigation

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Abstract— Flooding and excessive heat can threaten animals confined in cages or enclosures, especially when caretakers cannot respond immediately. This study developed and evaluated SMARTPAW, a climate-responsive smart animal shelter with an automatic emergency-release gate and temperature monitoring system designed to provide timely responses to hazardous environmental conditions. The prototype was tested under clear, muddy, and debris-laden floodwater conditions, with six trials per conditions, and at temperatures of 30°C, 35°C, 37.5°C, and 40°C. System performance was analyzed using one-way analysis of variance and Tukey HSD tests, while 20 pet owners evaluated the prototype using a 15-item questionnaire covering design, usability, and functionality. SMARTPAW achieved 100% flood-detection and emergency-gate opening success across all 18 trials, with mean total release times of 3.02s, 3.37s, and 4.07s for clear muddy, and debris-laden water, respectively. Flood-detection and gate-opening times varied significantly across selected conditions, with debris-laden water producing the longest overall response. The heat-monitoring system correctly activated or withheld alerts under all tested temperatures, while temperature-measurement error remained statistically comparable. Heat-alert activation also became faster at higher temperatures. The prototype received an overall rating of 4.49, interpreted as Excellent, with functionality receiving the highest evaluation. Overall, SMARTPAW demonstrated reliable flood detection, rapid emergency release, and effective heat- monitoring, indicating its potential as a supplementary safety system for confined animals in flood and heat-prone areas. Further field, durability, electrical safety, and animal-welfare evaluations are recommended before practical applications.

Keywords— animal enclosure, animal safety, automatic emergency release, flood detection, heat monitoring

I. INTRODUCTION

Climate change has become one of the most pressing environmental challenges of the twenty-first century, contributing to increasing risks from extreme heat, heavy rainfall, and flooding. According to the World Meteorological Organization (2024), climate change has intensified extreme weather events that threaten human lives, biodiversity, and environmental stability. Likewise, the Intergovernmental Panel on Climate Change (2023) emphasized that continued global warming is expected to increase the occurrence and severity of climate-related hazards, particularly in vulnerable regions. These conditions highlight the need for practical and adaptive technologies that can strengthen disaster preparedness and reduce the effects of extreme environmental events.

The Philippines is particularly vulnerable to climate-related hazards, including flooding and extreme heat. Floods are among the most frequently occurring natural hazards worldwide and have affected millions of people, while the Philippines has

consistently experienced numerous disaster events. These conditions emphasize the importance of strengthening preparedness measures in communities exposed to flooding and other climate-related hazards. As environmental risks increase, disaster preparedness must also consider the safety of companion animals, particularly those that may be confined in cages or enclosed shelters during emergencies.

Companion animals may face additional risks during disasters because they often depend on their owners for shelter, protection, and immediate assistance. The World Organisation for Animal Health (2023) recognizes the importance of including animals in disaster preparedness and emergency management. Animals confined in cages or enclosed areas may have limited opportunities to escape hazardous conditions when their caretakers are unavailable. Protopopova et al. (2021) further highlighted the effects of climate change and disasters on companion animals and the need for appropriate mitigation and adaptation strategies. These concerns demonstrate the importance of developing protective measures that can assist confined animals when immediate human intervention is not possible.

Flooding presents a particular concern for confined animals because rising water can enter cages and enclosed shelters, limiting an animal's ability to move to a safer location. Research on flood-monitoring technologies has demonstrated the value of environmental sensors and automated systems for detecting changes in water levels and providing timely responses. Studies reviewed in this research indicate that integrating sensors with embedded systems can improve environmental monitoring and the responsiveness of automated flood-related technologies. These developments provide a basis for applying water-level sensing to animal safety systems.

Extreme heat is another important environmental threat to companion animals. Increasing temperatures can create dangerous conditions, particularly in enclosed or poorly ventilated spaces. The American Veterinary Medical Association (2023) emphasizes the importance of monitoring environmental conditions and taking preventive measures to reduce heat-related risks in companion animals. Previous research has likewise indicated that environmental temperature and humidity can affect the risk of heat stress in dogs and other pets. These findings support the use of temperature-monitoring technologies as part of protective systems for animals exposed to elevated temperatures.

Environmental monitoring alone, however, may not provide sufficient protection when immediate action is required. Recent studies on automated systems have shown that sensors can be combined with motorized mechanisms to initiate responses when predefined environmental conditions are reached. Such systems can reduce dependence on continuous human intervention and provide timely responses during hazardous situations. For confined animals, an automated emergency mechanism may provide an additional means of responding to rising floodwater when a caretaker cannot immediately reach the animal.

Disaster preparedness frameworks have increasingly recognized the importance of combining monitoring, early warning, and timely response. The World Organisation for Animal Health (2023) emphasizes the inclusion of companion animals in disaster preparedness to reduce risks to animal welfare and strengthen community resilience. These approaches support the development of systems that do more than detect hazardous conditions by also providing an appropriate response once a critical threshold is reached.

Although existing studies have contributed to flood monitoring, heat-stress assessment, companion animal welfare, and automated emergency response, these areas are often addressed separately. The literature reviewed in this study indicates a limited integration of flood detection, temperature monitoring, and automated emergency response within a single shelter specifically designed to protect confined companion animals. This gap provides a basis for developing a system that combines environmental sensing with an immediate mechanical response.

To address this need, the present study developed SMARTPAW: a climate-responsive smart animal shelter with automated emergency door activation for flood and heat stress mitigation. The system integrates water-level and temperature sensors to detect hazardous environmental conditions and an automated mechanism designed to activate an emergency door when predefined conditions are reached. A backup power supply is also incorporated to support system operation during power interruptions. The prototype is intended to provide an additional safety measure for confined animals by combining environmental monitoring with automated emergency response. Its performance was evaluated under controlled or simulated flood and heat conditions, while its acceptability was assessed through evaluation by selected pet owners.

This study seeks to design and develop a climate-responsive smart animal shelter with automated emergency door activation for flood and heat stress mitigation and evaluate its effectiveness in detecting flood and heat stress conditions to improve animal safety during emergencies.

1.1 Research Question

This study seeks to design and develop a climate-responsive smart animal shelter with automated emergency door activation for flood and heat stress mitigation and evaluate its effectiveness in detecting flood and heat stress conditions to improve animal safety during emergencies.

Specifically, this study seeks to answer the following questions:

1. How effective is the automated emergency door activation system in providing a safe and timely exit for animals during emergencies?
2. How acceptable is SMARTPAW in terms of:
 - 2.1. Functionality,
 - 2.2. Reliability,
 - 2.3. Usability,
 - 2.4. Safety, and
 - 2.5. Durability?
3. How accurately does SMARTPAW detect hazardous floodwater levels and elevated temperatures under simulated conditions?

II. MATERIALS AND METHODS

The study used a prototype-development and experimental testing approach to design, construct, and evaluate SMARTPAW, a climate-responsive smart animal shelter with automated emergency door activation. The methodology focused on integrating environmental sensors, an automated mechanical system, and a backup power supply to allow the prototype to respond to hazardous flood and heat conditions. The prototype was evaluated through controlled or simulated environmental conditions to assess its functionality, reliability, and response performance.

2.1 Planning and System Design

The study began with the planning and design of SMARTPAW. The overall shelter layout, system flow, placement of components, and integration of the sensing and mechanical systems were determined before assembly. The design incorporated a water-level sensor for detecting flood conditions, a DHT22 temperature sensor for monitoring ambient temperature, a motor-driven emergency door mechanism, warning and display components, and a backup power source.

2.2 Collection of Materials and Components

The necessary electronic, mechanical, and structural components were gathered based on their intended functions and compatibility with the system. These included an Arduino Uno, water-level sensor, DHT22 temperature sensor, L298N motor driver, 12V high-torque DC gear motor, 12V power supply, 12V battery, battery charger module, wiring and connection components, and materials used to construct the shelter and emergency-door mechanism.

2.3 Assembly of SMARTPAW

The prototype was assembled by connecting the electronic components according to the designed circuit and integrating them with the shelter structure. The Arduino Uno served as the central controller, receiving input from the water-level and temperature sensors and processing the detected conditions. When the water level reached the preset threshold, the system activated the motor-driven emergency door mechanism. The prototype also included an audible warning and an LCD display for

system status and sensor readings. A backup battery was incorporated to maintain operation when the primary power source was unavailable.

2.4 Programming and System Integration

The system was programmed to process sensor readings and activate the appropriate responses based on predetermined environmental conditions. The programming and integration process ensured communication among the sensors, controller, motor system, warning device, and display. The components were tested together to ensure that the intended automated responses operated as a single functional system.

2.5 Testing Under Simulated Flood and Heat Conditions

The completed prototype was tested under controlled or simulated environmental conditions. For flood-response testing, six trials were conducted for each of three water conditions: clear, muddy, and debris-laden water, for a total of 18 trials. The tests measured flood detection and emergency-gate opening performance. For heat monitoring, the prototype was tested at 30 °C, 35°C, 37.5°C, and 40°C to determine whether the system correctly detected elevated temperatures and activated the appropriate warning response.

2.6 Data Collection, Evaluation, and Refinement

The results obtained from the prototype tests were recorded and analyzed to evaluate system performance. Flood-response performance was assessed based on detection success, detection time, gate-opening success, and gate-opening time. Heat-monitoring performance was evaluated based on temperature detection and alert activation. The prototype was also evaluated by selected pet owners using a structured questionnaire covering functionality, reliability, usability, safety, and durability. The collected results were used to identify necessary adjustments and improvements to the prototype.

III. RESULTS AND DISCUSSION

This chapter presents, analyzes, and interprets the results obtained from the performance testing and product evaluation of SmartPaw, an automated dog cage designed with a water-level-triggered emergency-release gate and an environmental heat-monitoring and alert system. The presentation covers flood-response performance, heat-monitoring performance, differences among controlled test conditions, and product evaluation by selected pet owners. Descriptive statistics are presented first, followed by one-way analysis of variance (ANOVA) and Tukey's Honestly Significant Difference (HSD) post-hoc test at an alpha level of .05.

3.1 Flood-Response Performance of SmartPaw

The study assessed the ability of the prototype to detect rising water and open its emergency gate under three controlled water conditions. Six bench trials were conducted for each condition. Table 1 reports the number of successful responses, the mean response times with standard deviations, and the derived total release time. These indicators show both reliability in completing the intended sequence and the speed with which a dog would gain access to the secured elevated escape area.

Table 1: Flood-Response Performance Under Controlled Water Conditions

Water condition	Detection success	Detection time, M $\pm$ SD (s)	Gate-opening success	Gate-opening time, M $\pm$ SD (s)	Total release time (s)
Clear water	6/6	1.25 $\pm$ 0.10 ^c	6/6	1.77 $\pm$ 0.08 ^b	3.02
Muddy water	6/6	1.55 $\pm$ 0.10 ^b	6/6	1.82 $\pm$ 0.08 ^b	3.37
Debris-laden water	6/6	2.02 $\pm$ 0.15 ^a	6/6	2.05 $\pm$ 0.10 ^a	4.07
Overall	18/18 (100%)	—	18/18 (100%)	—	—

Note. $n = 6$ trials per condition. Total release time is the sum of the mean detection and mean gate-opening times. Within each response-time column, means with different superscript letters differ significantly according to Tukey HSD at $\alpha = .05$. Em dash indicates that no overall mean was reported.

The results show that SmartPaw completed both water detection and gate opening in all 18 trials, corresponding to a 100% success rate for the tested sequence. Mean detection time increased from 1.25s in clear water to 1.55s in muddy water and 2.02s in debris-laden water. Thus, debris-laden water delayed detection by 0.77s, or approximately 61.6%, relative to clear water. Gate-opening time was comparatively stable in clear and muddy water at 1.77s and 1.82s, respectively, but rose to 2.05s in debris-laden water. The combined release sequence therefore took 3.02s in clear water, 3.37s in muddy water, and 4.07 s in debris-laden water. The debris condition was 1.05s, or about 34.8%, slower than the clear-water condition.

These patterns suggest that water quality affected the sensing stage more strongly than the actuation stage. Suspended particles or physical obstructions may have slowed consistent contact at the sensor or introduced variation around the detection point, whereas the gate mechanism remained relatively uniform once triggered. The 100% completion rate is encouraging for an early prototype, but the conclusion is restricted to six controlled trials per condition. Longer duration tests should include repeated wetting and drying, different debris sizes, splashing, sensor fouling, corrosion, power interruption, and false-trigger trials. The escape route must also lead only to a secure elevated area; opening directly into moving or contaminated floodwater could create a different hazard.

The results are broadly consistent with the principle that automated water-response systems can operate within seconds, while environmental conditions influence sensor behavior. Lee and Lee (2019) reported a response time of approximately 0.4–0.6s for a purpose-built submersion detector and emphasized the effect of temperature, humidity, rainfall, and foreign material on reliable sensing. SmartPaw’s observed detection times of 1.25–2.02s is slower, although the systems are not directly equivalent because the cited study evaluated a specialized detector rather than a cage-mounted release sequence. Hajjaj et al. (2020) developed an IoT-enabled autonomous floodgate and reported a 1–3s communication response for open-and-close commands. SmartPaw’s 3.02–4.07s total release times are of the same general order but include both local water detection and mechanical gate movement. The comparison supports the feasibility of rapid automation while also showing the need to isolate sensor delay, controller delay, and mechanical delay in future tests.

From an animal-disaster perspective, Glassey et al. (2024) documented major logistical and planning challenges during the rescue of more than 1,000 animals following the Edgcombe flood. SmartPaw addresses a narrower problem by providing a local emergency escape pathway for a confined dog when a caregiver cannot immediately intervene. It should therefore be viewed as a supplementary preparedness device, not as a replacement for evacuation planning, animal identification, a transport carrier, emergency contacts, and human supervision.

3.2 Heat-Monitoring Performance of SmartPaw

The study examines the prototype's ability to track environmental temperature and produce the intended warning response. Six trials were conducted at each reference condition. Table 2 presents the mean absolute error (MAE), the number of correct alert or non-alert decisions, and the alert-activation time. The 37.5°C condition was used as a trigger-response challenge; a separate MAE value was not recorded for that condition.

Table 2: *Heat-Sensor Accuracy and Alert Performance*

Reference temperature	Mean absolute error, $M \pm SD$ (°C)	Correct system response	Alert-activation time, $M \pm SD$ (s)
30.0 °C	0.117 ± 0.075^a	No alert, 6/6	Not applicable
35.0 °C	0.150 ± 0.105^a	Alert, 6/6	1.65 ± 0.10^a
37.5 °C	—	Alert, 6/6	1.45 ± 0.10^b
40.0 °C	0.217 ± 0.117^a	Alert, 6/6	1.25 ± 0.10^c

Note. $n = 6$ trials per condition. Means sharing the same superscript letter are not significantly different within a performance measure; different letters indicate a significant difference at $\alpha = .05$. The 30°C condition tested the correct non-alert response.

Em dash indicates that an MAE value was not recorded for the 37.5°C condition. The heat-monitoring results indicate correct system behavior in all 24 trials: the unit appropriately remained in the non-alert state at 30 °C and activated an alert in all trials at 35°C, 37.5°C, and 40°C. Across the three conditions with recorded error data, the average of the condition-level MAEs was approximately 0.161°C. MAE increased numerically from 0.117°C at 30 °C to 0.217 °C at 40 °C, but the superscript groupings indicate that these differences were not statistically significant. The data therefore suggest stable accuracy within the tested range, subject to confirmation with an independently calibrated reference instrument.

Alert activation became faster as the reference temperature increased: 1.65s at 35°C, 1.45s at 37.5°C, and 1.25s at 40°C. The 0.40 s reduction from 35°C to 40°C represents a 24.2% faster response. This likely reflects a stronger temperature excursion above the programmed alert threshold. A rapid alert is useful only if it is noticeable and leads to an appropriate action, such as moving the cage to a cooler area, improving ventilation, providing safe access to water, and checking the dog. The ambient sensor does not measure canine core temperature and cannot diagnose heat-related illness.

Wang (2023) demonstrated the feasibility of an STM32-based smart pet-house system that measured enclosure temperature, displayed readings, and transmitted data for real-time plotting. SmartPaw follows the same general direction of continuous environmental monitoring but extends the concept by pairing temperature alerts with a separate flood-triggered release feature. The need for early heat awareness is supported by veterinary evidence. Hall, Carter, and O'Neill (2020) identified 395 incident heat-related illness events among 905,543 dogs under UK primary veterinary care in 2016 and reported an event fatality rate of 14.18%, with increased risk among certain breeds, heavier dogs, older dogs, and brachycephalic dogs. Hall, Radford, and Carter (2022) further found that environmental exposure accounted for 19.6% of heat-related illness cases with a recorded trigger among small animals in their surveillance dataset.

These findings support the practical value of monitoring a confined animal's environment. They also caution against treating 35°C as a universal medical cutoff: an operational alert threshold should be configurable and interpreted with humidity, ventilation, duration of exposure, breed, body condition, age, health status, and veterinary guidance.

3.3 Differences Across Test Conditions

The study also determines whether the observed variation in response time and sensor error was statistically significant across the controlled test conditions. One-way ANOVA was used separately for flood-detection time, gate-opening time,

temperature absolute error, and heat-alert activation time. Table 3 presents the sums of squares, degrees of freedom, F statistics, p values, effect-size estimates, and decisions regarding the null hypotheses.

Table 3: *One-Way ANOVA for Flood- and Heat-Response Measures*

Performance measure	SS between	SS within	df	F	p	η^2	Decision
Flood-detection time	1.791	0.218	2, 15	61.53	< .001	.892	Reject H_0
Gate-opening time	0.274	0.117	2, 15	17.64	< .001	.701	Reject H_0
Temperature absolute error	0.031	0.152	2, 15	1.54	.247	.169	Fail to reject H_0
Heat-alert activation time	0.480	0.165	2, 15	21.82	< .001	.744	Reject H_0

Note. $\alpha = .05$. $\eta^2 = SS_{\text{between}} / (SS_{\text{between}} + SS_{\text{within}})$. The temperature-error ANOVA includes the 30 °C, 35 °C, and 40 °C groups; the alert-time ANOVA includes the 35 °C, 37.5 °C, and 40 °C groups. H_0 denotes the null hypothesis of equal means.

The ANOVA indicates significant differences among water conditions for flood-detection time, $F(2, 15) = 61.53$, $p < .001$, and gate-opening time, $F(2, 15) = 17.64$, $p < .001$. Water condition accounted for approximately 89.2% of the observed variance in detection time and 70.1% of the variance in gate-opening time based on η^2 . These results reject the corresponding null hypotheses and confirm that at least one water condition had a different mean response time.

The result supports the descriptive pattern in Table 1, where debris-laden water produced the longest delays.

Temperature absolute error did not differ significantly across 30°C, 35°C, and 40°C, $F(2, 15) = 1.54$, $p = .247$. The null hypothesis was therefore not rejected for sensor error. In contrast, alert-activation time differed significantly across 35°C, 37.5°C, and 40°C, $F(2, 15) = 21.82$, $p < .001$, with temperature condition accounting for approximately 74.4% of the observed variance. Statistical significance describes response-time differences under the tested conditions; it does not establish that every response is fast enough for all real emergencies.

Because only six trials were included per condition, the ANOVA has limited power for detecting small effects and remains sensitive to departures from normality or equal variance. The inferential results should therefore be interpreted within the scope of the tested prototype and controlled conditions. Additional device-to-device replication, residual diagnostics, outlier assessment, and larger samples would strengthen the generalizability of the findings.

A significant omnibus ANOVA identifies the presence of a mean difference but does not show which specific conditions differ. Accordingly, Tukey HSD comparisons were applied to the significant performance measures and were also reported for temperature error to confirm the absence of pairwise differences. Table 4 presents the adjusted pairwise probabilities and decisions.

Table 4: Tukey HSD Pairwise Comparisons Across Test Conditions

Performance measure	Comparison	Mean difference	Adjusted p	Decision
Flood-detection time	Muddy – clear	+0.30	.002	Significant
	Debris – clear	+0.77	< .001	Significant
	Debris – muddy	+0.47	< .001	Significant
Gate-opening time	Muddy – clear	+0.05	.599	Not significant
	Debris – clear	+0.28	< .001	Significant
	Debris – muddy	+0.23	.001	Significant
Temperature absolute error	35 °C – 30 °C	+0.033	.836	Not significant
	40 °C – 30 °C	+0.100	.229	Not significant
	40 °C – 35 °C	+0.067	.501	Not significant
Heat-alert activation time	37.5 °C – 35 °C	–0.20	.013 < .001	Significant
	40 °C – 35 °C	–0.40		Significant
	40 °C – 37.5 °C	–0.20	.013	Significant

Note. Mean differences are expressed in seconds for response-time measures and degrees Celsius for temperature absolute error. A positive value means that the first-named condition had a larger mean; a negative value means that it had a smaller mean. Significant at adjusted $p < .05$.

For flood detection, all three pairs differed significantly. Muddy water was 0.30s slower than clear water, debris-laden water was 0.77s slower than clear water, and debris-laden water was 0.47s slower than muddy water. For gate opening, clear and muddy water did not differ significantly ($p = .599$), whereas debris-laden water was slower than both clear water ($p < .001$) and muddy water ($p = .001$). The pattern distinguishes the two stages of the emergency sequence: turbidity alone affected detection, while the larger delay in gate actuation appeared only under the debris condition.

None of the temperature-error pairs was significant, with adjusted p values from .229 to .836. This supports the interpretation that measurement accuracy was statistically comparable at the tested temperatures. Conversely, every heat-alert activation pair was significant. The alert at 37.5°C was 0.20s faster than at 35°C, the alert at 40°C was 0.40s faster than at 35°C, and the alert at 40°C was 0.20s faster than at 37.5°C. The consistent ordering indicates progressively faster triggering as the test temperature rose farther above the alert point.

The condition effects agree with Lee and Lee's (2019) observation that submersion sensing can be strongly influenced by the surrounding environment and by foreign matter. Hajjaj et al. (2020) likewise recommended waterproof sensing hardware and field-specific testing before real deployment of an autonomous floodgate. SmartPaw's Tukey results make this design issue visible: the system retained complete success in the conducted trials, but debris significantly slowed both detection and gate movement. A practical revision should therefore include a guarded or self-draining sensor position, debris-resistant guides and hinges, periodic cleaning, and a self-test that can identify a blocked gate before an emergency.

For heat monitoring, the nonsignificant differences in MAE are consistent with the objective of stable measurement across the operating range, while the significant alert-time differences show that threshold distance influenced response speed. Wang's (2023) pet-house prototype establishes the feasibility of continuous enclosure-temperature monitoring, but the veterinary studies by Hall et al. (2020, 2022) show why system evaluation must extend beyond electronics. Field validation should examine the combined effects of temperature, humidity, airflow, enclosure occupancy, animal characteristics, and exposure duration because one ambient threshold may not be equally protective for all dogs.

3.4 Product Evaluation by Pet Owners

The fourth statement evaluates how intended users perceived the prototype after a demonstration of its structure and functions. Twenty pet owners answered a 15-item questionnaire covering design, usability, and functionality. Each item was rated on a five-point scale. Table 5 shows the verbal interpretation used for the item and criterion means.

Table 5: Interpretation of the Five-Point Product-Evaluation Scale

Weighted-mean range	Verbal interpretation	Operational meaning
4.21–5.00	Excellent	Feature was perceived to meet the criterion to a very high extent
3.41–4.20	Very Good	Feature was perceived to meet the criterion to a high extent
2.61–3.40	Good	Feature was perceived to meet the criterion to a moderate extent
1.81–2.60	Fair	Feature was perceived to meet the criterion to a low extent
1.00–1.80	Poor	Feature was perceived to meet the criterion to a very low extent

Note. The verbal labels are used only to summarize respondents' perceptions and do not constitute a safety certification or engineering compliance rating.

Using the scale in Table 5, Table 6 reports the mean and standard deviation for every questionnaire item. The table permits examination of the specific strengths perceived by the pet owners and identifies lower-rated features that warrant design refinement even when the verbal interpretation remains favorable.

Table 6: Item-Level Product Evaluation of SmartPaw by 20 Pet Owners

Criterion	No.	Evaluation item	Mean	SD	Interpretation
Design	1	The cage structure appeared sturdy and properly constructed.	4.55	0.51	Excellent
	2	The cage dimensions appeared adequate for the intended dog-size category.	4.35	0.59	Excellent
	3	The emergency gate opened toward the secured or elevated escape area.	4.45	0.60	Excellent
	4	Electronic components appeared protected from water and contact with the dog.	4.50	0.51	Excellent
	5	The overall physical arrangement of the prototype was appropriate.	4.55	0.51	Excellent
Usability	6	The display and indicator lights were easy to see and understand.	4.40	0.50	Excellent
	7	The temperature information was easy to interpret.	4.50	0.51	Excellent
	8	The warning alarm or notifications were noticeable.	4.45	0.51	Excellent
	9	The manual emergency-release control was easy to locate and operate.	4.30	0.66	Excellent
	10	The prototype was easy to operate after a brief demonstration.	4.45	0.51	Excellent
Functionality	11	The flood sensor responded promptly to rising water.	4.60	0.50	Excellent
	12	The emergency gate opened completely when activated.	4.65	0.49	Excellent
	13	The heat-sensor reading appeared stable during the demonstration.	4.45	0.60	Excellent

14	The system produced an appropriate alert under an elevated-temperature condition.	4.55	0.51	Excellent
15	SmartPaw appeared useful as an additional safety and monitoring device for dogs.	4.60	0.50	Excellent

Note. $n = 20$ pet owners; 15 items. Mean = arithmetic mean of item ratings; SD = standard deviation. Respondents evaluated the demonstrated prototype and did not assess performance during a real flood or hazardous heat event.

All 15 items received an “Excellent” interpretation, with means ranging from 4.30 to 4.65. The highest-rated item was complete gate opening ($M = 4.65$, $SD = 0.49$), followed by prompt flood-sensor response and the usefulness of SmartPaw as an additional safety device (both $M = 4.60$). These ratings indicate that respondents most strongly recognized the prototype’s core emergency function. The design items were also favorably evaluated, particularly the sturdiness of the cage and the overall physical arrangement (both $M = 4.55$).

The lowest mean was recorded for the ease of locating and operating the manual emergency-release control ($M = 4.30$, $SD = 0.66$). Although still interpreted as Excellent, it also showed the greatest variation in responses. The perceived adequacy of the cage dimensions ($M = 4.35$, $SD = 0.59$) and the clarity of the display and indicator lights ($M = 4.40$, $SD = 0.50$) were the next lowest. These results identify practical improvement priorities: enlarge and clearly label the manual release, position it where a caregiver can reach it without entering floodwater, provide tactile and color-contrast cues, improve display visibility, and specify the dog-size and weight limits for each cage configuration.

Table 7 consolidates the item scores into the three evaluation criteria and provides the overall product-evaluation result. The criterion summaries indicate which aspect of SmartPaw was most favorably perceived and whether any domain requires proportionally greater attention in the next design iteration.

Table 7 Criterion-Level Product Evaluation of SmartPaw

Evaluation criterion	Number of items	Mean	SD	Interpretation
Design	5	4.48	0.21	Excellent
Usability	5	4.42	0.26	Excellent
Functionality	5	4.57	0.25	Excellent
Overall	15	4.49	0.16	Excellent

Note. $n = 20$ pet owners. Criterion means summarize five items each. The overall mean summarizes all 15 questionnaire items. Functionality obtained the highest criterion mean ($M = 4.57$, $SD = 0.25$), followed by design ($M = 4.48$, $SD = 0.21$) and usability ($M = 4.42$, $SD = 0.26$).

The overall mean of 4.49 ($SD = 0.16$) was interpreted as Excellent. The 0.15-point range among criterion means is small, but usability remains the logical priority because the manual release, display, and controls must remain understandable during a stressful emergency. No inferential comparison among the three criterion means is reported because the respondent-level ratings needed for an appropriate repeated-measures analysis were not provided. Likewise, internal-consistency reliability, such as Cronbach’s alpha or omega, cannot be validly computed from means and standard deviations alone.

The favorable overall rating reflects perceived acceptability after a demonstration; it does not demonstrate long-term durability, animal comfort, behavioral acceptance, waterproofing, electrical safety, or successful operation during an actual disaster. A later evaluation should involve a larger and more diverse group of owners, structured task completion, measured error rates, time-on-task, open-ended feedback, and supervised trials that avoid exposing dogs to danger. Scores should also be analyzed by dog size, owner experience, and familiarity with electronic devices.

The product-evaluation findings are consistent with research showing that pet owners value monitoring technologies when they are understandable and provide actionable information. Re et al. (2023), for example, surveyed 50 owners of diabetic

dogs and cats using a flash glucose monitoring system; more than 80% considered it easier to use and less stressful than conventional glucose curves, and 92% perceived better diabetic control. That study also identified practical concerns—including sensor fixation, premature detachment, and long-term cost—that were not apparent from technical performance alone. SmartPaw's high usability and functionality means similarly indicate promising acceptability, but the instruments and products are different, so their numerical results should not be directly equated.

Wang (2023) focused on the technical feasibility of real-time temperature measurement in a smart pet house, whereas SmartPaw's questionnaire adds an owner-centered assessment of the structure, interface, emergency release, and alert functions. Together, these studies support evaluating both engineering performance and user experience. For SmartPaw, the next step is to connect these perspectives through task-based validation: pet owners should demonstrate that they can interpret an alert, operate the manual override, relocate the animal safely, and perform routine inspection and maintenance without assistance.

IV. CONCLUSION

The study concluded that SMARTPAW effectively performed its intended flood-response, emergency-release, heat-monitoring, and warning functions under the tested conditions. The system successfully detected flooding and completely opened the emergency gate in all 18 trials conducted under clear, muddy, and debris-laden water conditions. Its total emergency-release time remained below the five-second target, although debris caused a significant delay in detection and gate opening. The heat-monitoring system also produced readings close to the reference temperatures and correctly activated the warning at elevated temperature levels. Statistical analysis revealed a significant differences in flood-detection time, gate-opening time, and heat-alert activation time across the tested conditions, while temperature-measurement accuracy remained consistent. Furthermore, the prototype received an overall product-evaluation mean of 4.49, interpreted as Excellent, from 20 pet owners. These findings indicate that SmartPaw has potential as a supplementary safety and monitoring system for caged animals, particularly in areas vulnerable to flooding and excessive heat. However, further technical, environmental, and animal- welfare testing is necessary before the system can be recommended for actual household use.

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VI. RECOMMENDATIONS

Based on the results and conclusions, the following are hereby recommended:

1. The flood sensor and gate mechanism should be improved by adding protective screens and obstruction resistant components to minimize delays caused by mud and debris.
2. Waterproof electrical enclosures, insulated wiring, and a fail-safe manual release should be incorporated to ensure continued and safe operation during emergencies.
3. Long-term testing should be conducted under varying water depths, rising-water rates, debris loads, heat levels, humidity, power interruptions, repeated operation, and outdoor exposure.

4. The cage should be developed in different sizes and evaluated by veterinarians and animalwelfare specialists to ensure adequate space, ventilation, comfort, and structural safety for dogs and other confined animals.
5. Future product evaluations should involve more pet owners and task-based usability testing. Controlled field validation should also be completed before SmartPaw is introduced for household application.

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