Core opportunity: Prevent children from leaving and reduce staff cognitive/physical burden.

Framing:

- As interpreted from the RFP: the 2 main concerns are children escaping and supervisory burden.
- We don't have enough information about the community / area so we will stay away from permanent changes to the layout of the property since we don't really know what impacts that might have.
- We will not change the layout or add other dividers/barriers or change the designated play area because…
- We will keep the current positions of the passages because….

Scope:

- Considering only transition and play time
- Staff are always assumed to be within the walkway or playarea
- Children are always initially in the walkway or play area
- Do not permanently change the layout of the daycare outdoor space

Assumptions

- Transition duration << playtime duration

Current Justifications:

- Justify the conditions that each passage needs to meet.
- Justify having 3 states for the system (Off state, Transition state, playtime state)
  - When the children are safely in the building, the access to the daycare is open to any other stakeholder using the state thus justifying the need for a security state for when the children are inside the building.
- Also maybe adjust the map/diagram to show different types of gates (maybe show which ones are active at which times)
- There are 2 possibilities: either the system keeps children in, or a staff member keeps them in "manually".

Definitions

Passage	A **passage** is one of the 4 locations where gates are currently located.
Free Passage	A passage is said to be **free** to a group of people if a person from that group is able to independently traverse the passage.
Blocked Passage	A passage is said to be **blocked** to a group of people if no person from that group is able to independently traverse the passage. **Blocked** is the opposite of **free**.
Access	**Access** refers to the conditions of freedom and blockage to different groups.
Transition	A **transition** is any period of time when staff members or children are in the walkway.
Playtime	**Playtime** is the period of time when staff members and children are in the play area, but no staff members or children are in the walkway.
Clear time	**Clear time** is any period of time when there are no staff members or children in the play area or the walkway.
Outsiders	**Outsiders** are any users of the outdoor space of the daycare that are not staff or children.

Requirements and Evaluation Criteria

Key functional requirements and performance requirements

- **Access matrix:** The system shall satisfy the access matrix below.

	Passage 1	Passage 2	Passage 3	Passage 4
Transition	Blocked to children Free to staff Blocked to parents	Blocked to children Free to staff Blocked to parents	No req for children Free to staff No req for parents	Blocked to children Free to staff Blocked to parents
Playtime	No req for children Free to staff Free to parents	No req for children Free to staff Free to parents	Blocked to children Free to staff Free to parents	Blocked to children Free to staff Free to parents
Clear time	Free to other users	Free to other users	Free to other users	Free to other users

  - **Bottom gap distance:** The distance from the ground to the bottom of the gate shall be ≤ 89 mm [1].
  - **Fastening control height:** The height of the gate fastening controls shall be between 1548 mm and 1808 mm above the ground [Calculation 1] [3].
  - **Outside reach prevention:** The height of the gate shall be $> \frac{2260+L}{2}$ mm above the ground, where L is the height of the latch in mm [Calculation 2].
  - **Force resistance:** The gate shall be able to withstand ≥ 944 N force applied by children when fastened [Calculation 3].
  - **Variable parental access:** Staff shall be able to enable and disable controls to the gate fastening mechanisms that are accessible to parents.
- **Staff attention**: The system shall bring staff to attention whenever any person (e.g. staff or parents) traverses a gate that is required to be blocked to children.
  - **Vibration Frequency**: The vibration frequency of the wearable shall be between 8-16 Hz [11].

Secondary requirements

- **Emergency evacuation:** The system shall allow staff and children to exit the play area and walkway in an emergency.
  - **Evacuation time:** Staff shall be able to open gates in ≤ 15 s [6].
  - **Evacuation force:** Shall require staff to exert ≤ 90 N of force to traverse passages when evacuating the play area or walkway [6].
  - **Straightforward evacuation:** Staff shall be able to exit the play area and walkway "without requiring keys, special devices, or specialized knowledge of the door opening mechanism" [7].
  - **Manual evacuation**: The system opening shall be able to function without an external power source [8].
- **Scent-free/scent-aware:** The system shall not release scented products in the walkway or play area [9].
- **Operating temperatures:** The system shall function in any temperature between –27 °C to 38 °C [10].
- **Operation time:** The system shall function for ≥ 3.5 h of playtime and transition time (combined) per day.

Evaluation criteria

- **Setup time:** The less time [s] per transition that the staff interacts with the gates and gate systems, the better.
- **Attention delay:** The shorter the delay [s] between when {a person traverses a gate blocked to children} and {when staff is brought to attention}, the better.
- **Play interference:** The fewer children [# children] that are brought to attention when staff are brought to attention, the better.
- **Staff attention frequency:** The less frequently [#-of-times/hour] staff are notified by the system, the better.
- **Staff attention time:** The less time [minutes] staff spend {interacting with} or {paying attention to} the gate system per hour of playtime, the better.
- **Staff traversal time**: The less time [s] it takes for staff to traverse each gate, the better.
- **Wearable comfort:** The less obtrusive the wearable location (as described by Gemperle et al.), the better [12].
- **Overlapping functions:** The fewer the number of components with overlapping functions, the better.
- **Material use:** The less material used [kg] the better.

Source Extracts

Requirement: Bottom Gap Distance

[1] Manitoba School Boards Association, "Public Playground Safety Manual," Mar. 2022. Available: https://www.mbschoolboards.ca/wp-content/uploads/2022/10/Public-Playground-Safety-Manual-March-2022.pdf

Hazards

Head Entrapment

This is a serious concern since it could lead to strangulation and death. Certain openings could present an entrapment hazard if the distance between openings is greater than 89 mm (3.5 inches) and less than 229 mm (9 inches). **Bicycle helmets should never be allowed to be worn while using a playstructure as they may increase the entrapment hazard.**

Requirement: Fastening Control Height

[2] Highway Safety Research Institute The University of Michigan Ann Arbor, "Anthropometry of Infants, Children, and Youths," *National Institute of Standards and Technology (.gov)*, May 19, 1977. https://math.nist.gov/~SRessler/anthrokids/child77lnk.pdf (accessed 2AD).

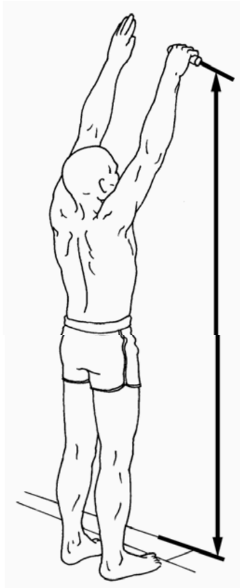
WEIGHT, STATURE, STANDING, AND SITTING MEASUREMENTS
(Males and Females - Ages 4.5 to 5.5 Years)

Measurement	Descriptive Statistics							
	N	Mean	s.d.	Min	5th	50th	95th	Max
Weight	271	18.3	2.5	13.7	15.1	17.9	22.1	36.0
Stature	271	108.3	4.7	96.5	100.6	108.5	115.8	124.4
Vertical Grip Reach	73	126.1	7.0	108.9	113.1	126.2	136.9	141.1
Frontal Grip Reach	74	45.4	3.4	38.0	40.4	45.2	51.5	55.3
Lateral Grip Reach	72	59.7	3.9	51.9	52.5	59.2	66.0	72.1
Step Height	75	42.9	6.5	30.8	31.9	42.7	53.0	57.0
Supine Stature	26	112.5	3.9	105.5	105.9	112.1	119.1	119.5
Standing CG (from feet)	26	64.5	2.3	60.5	60.6	64.5	68.2	69.0
Standing CG (% Stature)	26	57.3	0.9	55.2	55.4	57.2	58.3	59.5
Erect Sitting Height	265	60.5	2.7	52.6	56.0	60.5	64.9	70.3
Eye Height (Sitting)	90	49.8	2.8	41.5	45.2	49.7	54.5	56.9
Max Hip Breadth (Seated)	257	20.7	1.3	17.3	18.6	20.5	23.0	24.6
Maximum Thigh Breadth	85	20.9	1.4	18.4	18.7	20.6	22.9	25.8
Thigh Clearence	89	8.9	1.1	6.0	6.7	9.0	10.4	11.3
Buttock-Knee Length	267	33.9	1.9	28.4	30.9	33.8	37.0	41.2
Knee Height	241	32.3	2.0	28.1	29.2	32.2	35.6	38.2
Supine Sitting Height	27	63.2	2.8	57.0	57.4	63.0	67.1	68.0
Seated CG (above seat)	27	20.6	1.0	19.2	19.2	20.3	22.1	22.4
Seated CG (% Sit Hgt)	27	32.6	1.8	29.9	29.9	32.2	35.1	38.5
Seated CG (from back)	25	14.8	2.1	12.0	12.1	14.4	18.6	21.1
Seated CG (% Butt-Knee)	25	43.0	5.5	33.3	33.8	42.2	54.2	55.0

[3] C. C. Gordon, “Anthropometric Data,” Apr. 2006. Available:
https://multisite.eos.ncsu.edu/www-ergocenter-ncsu-edu/wp-content/uploads/sites/18/2016/06/Anthropometric-Detailed-Data-Tables.pdf

Vertical Grip Reach

FEMALE N = 2208 Centimeters		Inches	MALE N = 1774 Centimeters		Inches
194.73	**Mean**	76.67	210.74	**Mean**	82.97
8.71	**Std Dev**	3.43	9.24	**Std Dev**	3.64
226.00	**Maximum**	88.98	253.40	**Maximum**	99.76
162.20	**Minimum**	63.86	169.90	**Minimum**	66.89
	Percentiles			**Percentiles**	
174.63	1st	68.75	189.28	1st	74.52
177.23	2nd	69.78	192.01	2nd	75.60
178.79	3rd	70.39	193.66	3rd	76.25
180.83	5th	71.19	195.84	5th	77.10
183.85	10th	72.38	199.08	10th	78.38
185.85	15th	73.17	201.25	15th	79.23
187.43	20th	73.79	202.96	20th	79.91
188.81	25th	74.33	204.46	25th	80.49
190.05	30th	74.82	205.80	30th	81.02
191.21	35th	75.28	207.05	35th	81.52
192.32	40th	75.72	208.25	40th	81.99
193.41	45th	76.15	209.59	45th	82.45
194.50	50th	76.57	210.59	50th	82.91
195.60	55th	77.01	211.77	55th	83.38
196.73	60th	77.45	212.97	60th	83.85
197.90	65th	77.91	214.23	65th	84.34
199.16	70th	78.41	215.55	70th	84.86
200.53	75th	78.95	216.99	75th	85.43
202.07	80th	79.56	218.60	80th	86.06
203.87	85th	80.26	220.45	85th	86.79
206.14	90th	81.16	222.76	90th	87.70
209.44	95th	82.46	226.04	95th	88.99
211.51	97th	83.27	228.03	97th	89.77
212.96	98th	83.84	229.39	98th	90.31
215.10	99th	84.64	231.31	99th	91.07



[4] K. Koren, R. Pišot, and B. Šimunič, “VERTICAL JUMP HEIGHT IN YOUNG CHILDREN – A LONGITUDINAL STUDY IN 4-TO 6-YEAR-OLD CHILDREN,” *ANNALES KINESIOLOGIAE* •, vol. 7, no. 2, 2016, Accessed: Apr. 07, 2026. [Online]. Available: https://distantreader.org/stacks/journals/ak/ak-121.pdf

Parameter	Sex	4 years	5 years	6 years	P_{sex} (η^2)	P_{age} (η^2)	$P_{age\ x\ sex}$ (η^2)
Body height / cm	Boys	108±4.8	115±5.3	121±5.6	.073	<.001 (.943)	.339
	Girls	108±4.4	116±5.0	123±5.8			
Body mass / kg	Boys	18.2±2.5	20.5±3.0	23.6±3.7	.494	<.001 (.877)	.364
	Girls	18.5±2.8	21.3±3.6	24.0±4.2			
Fat mass / %	Boys	14.2±2.4	14.6±3.3	17.2±4.7	.001 (.133)	<.001 (.293)	.701
	Girls	16.7±2.5	17.1±3.8	19.2±4.2			
Muscle mass / kg	Boys	5.7±0.9	6.6±1.0	7.7±1.2	.002 (.116)	<.001 (.881)	.194
	Girls	5.1±0.8	6.0±0.9	6.9±1.1			
CMJ height without arms / cm	Boys	9.1±3.1	11.8±3.3	13.2±3.4	.337	<.001 (.620)	.072
	Girls	8.9±2.9	12.8±3.1	14.3±2.9			
CMJ height with arms / cm	Boys	9.9±3.3	12.6±3.2	14.7±3.3	.140	<.001 (.632)	.095
	Girls	8.9±2.9	14.2±3.7	15.8±3.2			
Coordinated jumpers / %	Boys	35	53	79		<.001 (.881)	
	Girls	33	76	87			

CMJ – countermovement jump
Coordinated jumpers - subjects with excellent jumping coordination
η^2 – partial eta-squared

Calculation 1

Minimum height = 136.9 cm *(95th %tile vertical standing reaching height of 5 year olds [2])*
+ 14.2 + 3.7 *(high vertical jumps from 5 year olds [4])*
= 154.8 cm = 1548 mm

Requirement: Outside Reach Prevention

Calculation 2

R = 95th percentile reach height = 2260 mm [3]
h = height of gate in mm
L = latch height in mm

To prevent people from outside from reaching over the gate and touching the latch, we need

$$h + (h - L) > R \Rightarrow 2h - L > 2260 \Rightarrow h > \frac{2260+L}{2}\,mm.$$

For a latch height of $L = 1548\,mm$, we need $h > \frac{2260+1548}{2} = 1904\,mm$. So choose 1950 mm.

To prevent people from outside from reaching around the side of the gate and touching the latch, we need to block a certain horizontal distance from the gate latch.

E.g. for gate 4:

w = width of horizontal barrier on each side of gate latch

f = fence height = 1250 mm (taken as the lowest current gate height)

So we need $w > R - f \Rightarrow w > 2260 - 1250 = 1010\,mm$. The width of the gate is greater than 1010 mm, so we don't need a barrier on the non-latch side. On the latch-side, we need a barrier width of at least 1010 mm.

Requirement: Force Resistance

[5] P. E. de Winter, L. P. A. Steenbekkers, and J. J. Houtkamp, “Pushing and pulling forces exerted by children,” *International Journal for Consumer and Product Safety*, vol. 1, no. 4, pp. 243–258, Dec. 1994, doi: https://doi.org/10.1080/09298349408945742.

Table 6	*boys*					*girls*					*boys + girls*		
age [years]	*n*	*s*	*minimum*	$\bar{x}$	*maximum*	*n*	*s*	*minimum*	$\bar{x}$	*maximum*	*n*	*s*	$\bar{x}$
4	11	215	152	370	926	9	145	123	309	641	20	185	343
5	19	288	98	470	1028	16	228	89	408	820	35	261	442
6	5	39	326	372	426	8	257	180	516	933	13	211	461
7	12	286	320	718	1098	13	333	180	600	1234	25	310	657
8	15	365	308	660	1829	9	378	370	793	1528	24	367	710
9	14	427	462	1024	1925	14	436	351	997	1843	28	424	1011
10	8	456	449	1207	1746	5	383	821	1321	1830	13	417	1251
11	10	572	361	1007	1950	13	354	425	809	1421	23	461	895
12	14	516	552	1291	1959	8	223	392	740	1134	22	505	1091

TABLE 5. Pushing force with arms when sitting [N]

TABLE 6. Pushing force with legs when sitting [N]

EXTREME VALUES The younger the children are, the more difficult it is to make them feel comfortable and to motivate them to exert the largest force they can. The relative difference between the lowest and the highest value measured is in all cases largest for the children in the age groups of 4 and 5 years. This can also be seen in tables 3 to 6, where the smallest and the largest force per age group and sex are presented.

Calculation 3

Standard deviation calculation:

We will try to approximate the 95th percentile force that a 5-year-old child can exert. Mean force for 5-year-old was found to be $\mu = 470N$, with a standard deviation of $288N$ [44]. Thus, we can approximate the distribution with the function

$$f(F) = \frac{1}{288\sqrt{2\pi}}\exp\left(-\frac{(F-470)^2}{2\times288^2}\right).$$

We seek k such that $\int_{-\infty}^{k} f(F)\,dF = 0.95$, which results in the 95th percentile $k = 944\ N$.

Requirement: Evacuation Time, Evaluation Force

[6] Government of Canada, "Building Safety (Door Release) - 922-1-IPG-044 - Canada.ca," *Canada.ca*, 2026. https://www.canada.ca/en/employment-social-development/programs/laws-regulations/labour/interpretations-policies/044.html

Sentence 3.4.7.12.(15) of the 1985 NBC and Sentence 3.4.6.15.(4) of the 1990 NBC permit the use of electromagnetic locks that do not incorporate latches, pins or other similar devices to keep the door in the closed position on exit doors other than doors leading directly from a Group F, Division 1 occupancy provided:

a. the building is equipped with a fire alarm system;
b. the locking device releases immediately
   - upon initiation of a fire alarm signal,
   - in the event of a power failure, and
   - upon actuation of a manually operated switch accessible only to authorized personnel;
c. a force of not more than 90 N applied to the door opening hardware initiates an irreversible process that will release the locking device within 15 s and not relock until the door has been opened;
d. upon release, the locking device must be reset manually by the actuation of the switch in Subclause (b)(iii); and
e. a legible sign is permanently mounted on the exit door to indicate that the locking device will release within 15 s of applying pressure to the door-opening hardware.

Requirement: Straightforward Evaluation

[7] The Government of Ontario, "Law Document English View," *Ontario.ca*, Jul. 24, 2014. https://www.ontario.ca/laws/regulation/r07213

2.7.2.2. (1) Except as permitted in Sentences (2) and (3), locking, latching and other fastening devices on

(a) every required exit door, and

(b) every door that opens into or is located within

(i) a **public corridor**,

(ii) a facility that provides **access to exit** from a **suite**, or

(iii) a facility that provides **access to exit** from a room serving patients or residents in a **care or detention occupancy**

shall be such that the door can be readily opened to permit egress without requiring keys, special devices or specialized knowledge of the door opening mechanism.

(2) Except for a door in an elementary or secondary school or a door leading directly from a high hazard industrial occupancy, a door in an access to exit or an exit door may be equipped with an electromagnetic locking device that is approved or complies with the Building Code.

Requirement: Manual evacuation

[8] Standard for Door, Drapery, Gate, Louver, and Window Operators and Systems, ANSI/CAN/UL 325:2025, Underwriters Laboratories, Northbrook, IL, USA, 2025.

30.3 Interruption of power

30.3.1 Interruption of power shall not preclude the opening of a sliding or swinging pedestrian door. A door operator intended for use with a sliding or swinging pedestrian door and that is intended to be sold without the door shall not, in case of interruption of power, interfere with the opening of the door.

30.3.2 Unless compliance with 30.3.1 is apparent from the design of the door, a door operator is to be subjected to simulated interruption of power, and is considered to comply with 30.3.1 if the force required to open the door manually is not more than 222.4 N (50 lbf). The force is to be applied in a manner and at a location representative of manual opening of the door. A door operator that is intended to be sold without the door is to be tested using a door that is:

a) Recommended by the manufacturer for use with the operator, and

b) Most difficult to operate manually.

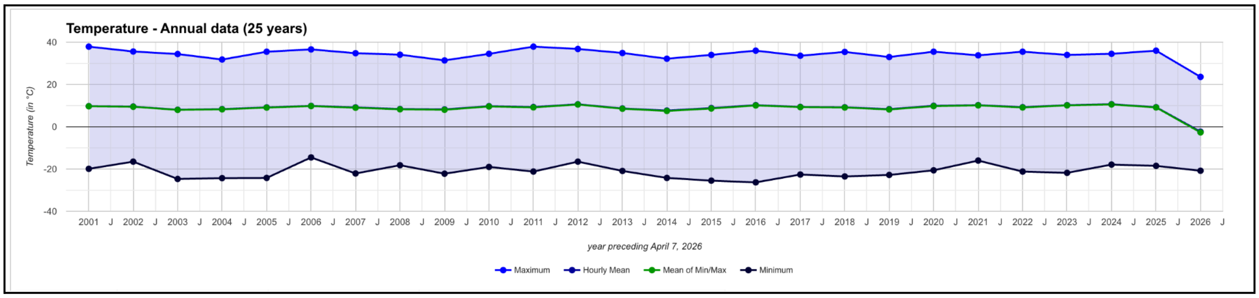
Requirement: Scent-free/scent-aware

[9] C. Jaén and P. Dalton, "Asthma and odors: The role of risk perception in asthma exacerbation," *Journal of Psychosomatic Research*, vol. 77, no. 4, pp. 302–308, Oct. 2014, doi: https://doi.org/10.1016/j.jpsychores.2014.07.002.

Fragrances and strong odors have been characterized as putative triggers that may exacerbate asthma symptoms and many asthmatics readily avoid odors and fragranced products. However, the mechanism by which exposure to pure, non-irritating odorants can elicit an adverse reaction in asthmatic patients is still unclear and may involve both physiological and psychological processes. The aim of this study was to investigate how beliefs about an odors relationship to asthmatic symptoms could affect the physiological and psychological ‘ responses of asthmatics.

Requirement: Operating temperatures

[10] WeatherStats, “Temperature - Annual data for Toronto,” *Amateur Weather Statistics for Toronto, Ontario*. https://toronto.weatherstats.ca/charts/temperature-yearly.html



Requirement: Vibration Frequency

[11] imc, “Vibration testing in hand-held power tools,” Aug. 11, 2018. APP_eng_Vibration_Testing_in_Hand-held_Power_Tools-1.pdf

> **Standardized measurement method according to EN ISO 5349-1/2**
>
> This procedure is strictly in accordance with the EN ISO 5349-1/2. Here, a triaxial vibration measurement is carried out on the tool with acceleration sensors mounted close to the hand to simultaneously measure vibrations in all three orthogonal directions. These measurements focus on vibrations in the frequency range between 6.3 Hz to 1250 Hz, thus covering the range that is most sensitive to humans: 8 Hz to 16 Hz. With the help of a weighting filter for hand-arm vibration, the frequency-weighted RMS value is determined from the three triaxial channels. These values must conform to the ISO 5349 values set forth to protect against injury from the prolonged use of a power tool. The weighting filter is defined by means of appropriate imc STUDIO and imc FAMOS sequences. An “automated evaluation” then performs all further calculations in accordance with the Standard.

Evaluation Criteria: Wearable Comfort

[12] F. Gemperle, C. Kasabach, J. Stivoric, M. Bauer, and R. Martin, "Design for Wearability," 1998. Available: https://www.andrew.cmu.edu/course/15-821/assets/READINGS/PAPERS/gemperle1998.pdf

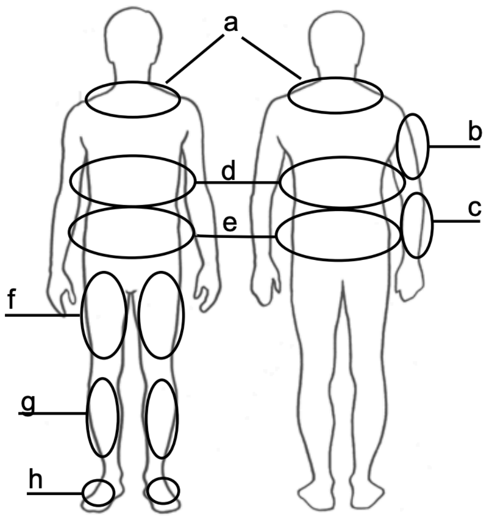


Fig. 1, The general areas we have found to be the most unobtrusive for wearable objects are: (a) collar area, (b) rear of the upper arm, (c) forearm, (d)rear, side, and front ribcage, (e) waist and hips, (f) thigh, (g) shin, and (h) top of the foot.

Converging

Converging based on key functional requirements

Options for the function of "block passages":

- Modify existing gate to cover bottom gap
- Replace gate
- Unpleasant sensory experience (foul smell, loud sounds near passages,...) - not a guaranteed blockage
- Security guard - limited resources
- Psychological deterrent (brainwashing) - not realistic
- Magnetic device that repels people from gate - adds to staff burden, inhuman
- Temporary fence around play area and walkway - increases staff burden of setting up the fence each time
- Leashes - inhumane

Options for the function of "bring staff to attention when child access matrix is not satisfied":

- Mobile phone notification - don't know how long their phone battery lasts, or whether their personal phone battery dies - if something doesn't always work, then it doesn't work
- Wearable on staff that notifies staff
- Local visual indication at passages - staff might be on the other side of the L-shape
- Local auditory indication at passages - staff might be on the other side of the L-shape
- Local olfactory indication at passages - staff might be on the other side of the L-shape
- Global visual indication around play area - no - play interference
- Global auditory indication around play area - play interference
- Global olfactory (smell) indication around play area - play interference

Design Decisions (so far):

1. To modify the existing gate or use a new gate.
2. To use a wearable notification to bring staff to attention.

Given this, we can think of ways to **differentiate access between children and staff** and **inside access vs outside access**.

Options for to differentiate access between children and staff (block children + pass staff)

- Fastening system that requires dexterity/motor-skills/coordination to operate (e.g. multi-action latch, medicine bottle) - doesn't ensure children cannot open it
- Fastening system controlled from height inaccessible to children
- Fastening system that requires possessions to operate (e.g. keys, keycard access only, portable electronic switch) - eliminate by emergency evacuation mechanism
- Biometric access (e.g. fingerprint, face ID) - not sure of the staff privacy preferences, so better to be safe than sorry
- Fastening system that requires secret knowledge (e.g. pin, password) - eliminate by emergency evacuation mechanism
- Fastening system that requires answering a reading/writing/math question to control - inhumane in case of emergency - results from this research study suggests that shock decrease the working memory [1], which directly affects the staff's ability to comprehend, problem-solve, and reason [2]. Since reading/writing/math questions require these components, this concept will delay the escape during emergencies.
- Fastening system that requires strength greater than what children can exert (e.g. large force required) - children can exert > 90N but emergency evacuation mechanism requires < 90N
- Lock gate completely during playtime and transition - doesn't accomplish the function
- Detect wearables on children and lock gate - increases workload and burden on staff
- Camouflaged gate or latch - not realistic
- Brain-operation of gate by staff - unrealistic for Praxis II
- Gate opening granted to staff by another staff member located inside the building - not sure about availability of other staff, so better safe than sorry

- Hand size restriction - can easily be overcome by using more than one hand

Options to distinguish between outside access and inside access

- Lock from inside (e.g. household bathroom door, but not necessarily same mechanism)
- Latch only located on inside of gate (e.g. public washroom stall door, but not necessarily same mechanism) - this would let gate swing around during clear time, and we don't know if that's ok with other users of the space
- Door opening controlled from inside the building - not sure of availability of staff members in the building

Design Decisions (so far):

1. To modify the existing gate or use a new gate
2. To use a wearable notification to bring staff to attention.
3. Gate fastenings can only be controlled at a restrictive height to children
4. Fastenings must be blocked from outside using a locking mechanism

Observation: different gates need to fulfill different functions at different times. This implies we need to be able to change between different functions at different times.

Diverging and converging within chosen design concept

Morph Chart

Switch functions of gates	Fasten gate in closed position	Wearable Location	Sensory Alert Type
Control located on staff wearable	Pin in hole	Wrist wearable	Sound
Control activated with latch	Elastic band - burden on staff	Earpiece	Smell - can be easily affected by environment or personal circumstances
Separate control at each gate	Lever - does not support parental or staff	Ankle bands	Light
Global control for gates at door and gate 3	Electromagnet	Neck band / necklace	Touch (vibration)
Global control for gates indoors - not sure of the availability of staff inside, so better safe than sorry	Swing/chain (hotel room locks) that allow some opening - does not support parental or staff	In shoes	Taste - can be easily affected by environment or personal circumstances
	Catch mechanism - does not support parental or staff	Staff clothing	
	Tongue	Glasses	
	Gravity Latch		

Design Decisions (so far):

Now we have 3 decisions to make:

- System for switching functions of gates
- Pin in hole vs. electromagnet vs. tongue vs gravity latch
- Wearable location and sensory alert type

To do this, we are doing **Pugh charts** and **testing** to converge down.

Pugh charts

Switch functions of gates

	Reference: Control located on staff wearable	Control activated with latch	Separate control at each gate	Global control for gates at door and gate 3
Staff workload criterion	0	+	-	0
Simplicity	0	-	-	0

	Reference: Control activated with latch	Control located on staff wearable	Global control for gates at door and gate 3
Staff workload criterion	0	0	0
Simplicity	0	+	+

	Reference: Global control for gates at door and gate 3	Control located on staff wearable
Staff workload criterion	0	0
Simplicity	0	+

Conclusion: control location on staff wearable

Grab Attention

	Earpiece that plays sound (Reference)	Visual Indication wearable design	Wrist wearable that vibrates
Attention delay	0	– *Comparatively slower reaction to light*	0 *Wearable is always in contact with body, similar to earpiece; reaction time to tactile stimulation similar to reaction to sound ~ 150 ms*
Wearable Comfort	0	0 *Similar level of obtrusiveness as earpiece*	+ *Wrist is less sensitive than ear. Additionally, the volume of the earpiece would have to be loud to be heard over the children playing.*

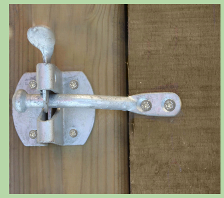
Conclusion: From this we landed on a wrist wearable design that vibrates to grab the attention of the staff.

Open/close detection

Metrics	**Reed switch**	**Ultrasonic sensor**	**IR (Infrared Motion sensors)**	**Photoresistor**
Accuracy	0	- *15% false rates Accuracy is affected for temperature of more than 5 - 10 C*	- *38% false rates Affected by ambient light, dust, and temperature variations (worse accuracy than ultrasonic)*	- *Affected by temperature, takes time to recover from light exposure (not instantaneous)*
Durability	0 *Withstand against dirt, dust, moisture – long life expectancy (Long life, 10^9 operations)*	- *Withstand smoke or black materials, but incorrect readings with a heavy build-up of dirt or water*	- *Less durable than ultrasonic sensors*	- *Less durable than reed switch since they are sensitive to the environment*

Conclusion: reed switch

Research/Testing

Requirement/EC	**Pin latch** 	**Electromagnet** 	**Automatic (gravity) latch** 	**Lever latch** 
Withstanding Force *(removed)*		2225 N		
Staff time spent interacting with latch (relative)	>1	1	1	>1
Power consumption between traversals	0	9 W	0	0
User required to close to gate manually upon entering*	0	0	0	1

Note: The Withstanding Force requirement is removed because all gates must withstand at least 9000 N, which satisfy the force resistance requirement.

Material: Teak

Properties of Teak

- Teak is naturally frost resistant
- Teak's natural oils make it water resistant, warps and cracks don't happen
- Snow has little to no impact on teak, but prolonged exposure can cause surface graying

Why don't we choose anti-icing coatings?

lows for enhanced anti-icing performance through molecular structure optimization and incorporation of functional additives. For example, integrating nanotechnology with polymer materials can impart superhydrophobic or super-anti-icing properties, further improving anti-icing efficacy. Therefore, despite being at the developmental stage, the unique attributes and broad applicability of polymer materials make them highly promising candidates for future anti-icing solutions.

5 CHALLENGES FOR KEY MATERIALS

Despite significant advancements in the research and development of key materials for snow and frost prevention, practical applications and large-scale promotions still encounter numerous challenges. These challenges can be summarized as follows.

Mechanical stability and universality: The formation process and final state of ice and snow are complex and variable and are influenced by diverse external environmental conditions. Polymer-based materials often exhibit weak intermolecular forces, leading to increased brittleness and reduced mechanical strength under extremely cold conditions, which makes them prone to cracking and damage. Different icing scenarios require materials with varying response mechanisms and the development of polymers or polymer composites that are adaptable to various conditions. For example, anti-icing measures for transmission lines in alpine regions struggle to balance strong winds, low temperatures, and different icing conditions, resulting in suboptimal performance.

Influence of external conditions and degradation dilemma: Polymer-based materials are significantly affected by external factors, such as high temperatures, which cause softening and decomposition, limiting their application range. While their degradation characteristics support recycling and align with green development concepts, they also negatively impact the material service life. In cold weather applications, freeze-thaw cycles accelerate material degradation, reduce physical properties, and shorten the useful life. Frequent freeze-thaw cycles in northern winters lead to rapid wear and degradation of polymer-based de-icing materials, diminish-

Sustainability (SDGs)

SDG 4

4.a Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, non-violent, inclusive and effective learning environments for all

In our design: The daycare is shared by different community members, so the gate must be easy and quick for everyone, including children, parents, and people with different needs.

SDG 12

12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment.

In our design, we avoided alarm systems that use chemicals or strong smells in the converge stage. That means less pollution to air and soil, while still keeping children safe.

12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse.

In our design, we chose teak wood as the material for our gate. It lasts long, can be recycled, and reduces waste - from prevention to reuse.

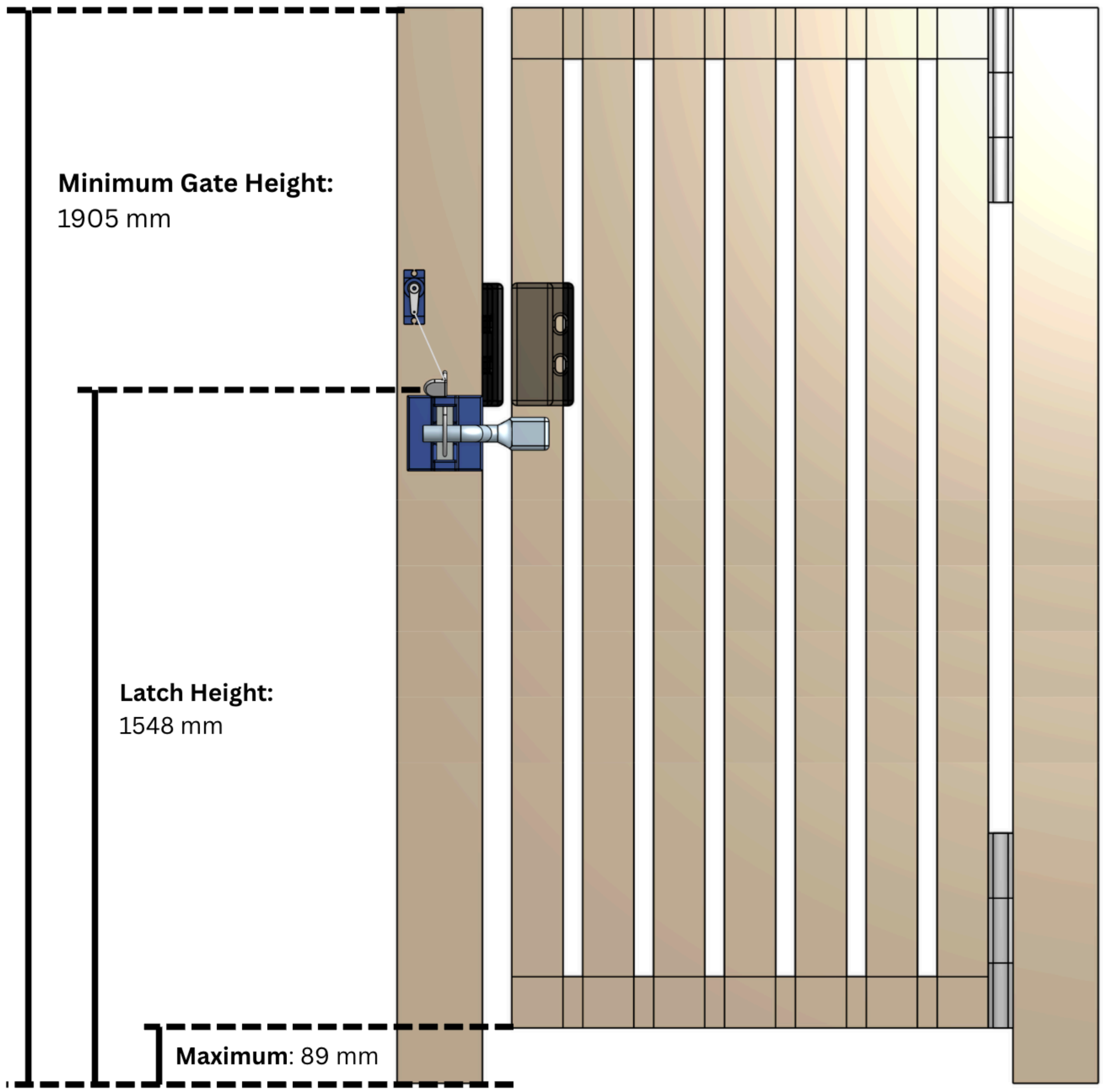
SDG 16

16.2 End abuse, exploitation, trafficking and all forms of violence against and torture of children.

In our design, we removed any design that could hurt children physically or mentally. For example, no scary stories, no horror themes, and no brainwashing-like messages.

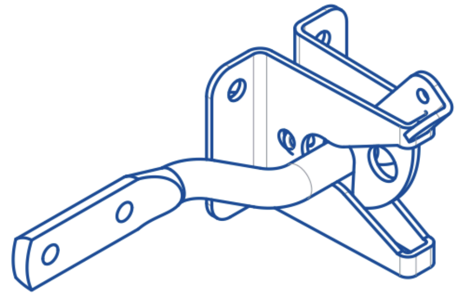
Prototypes

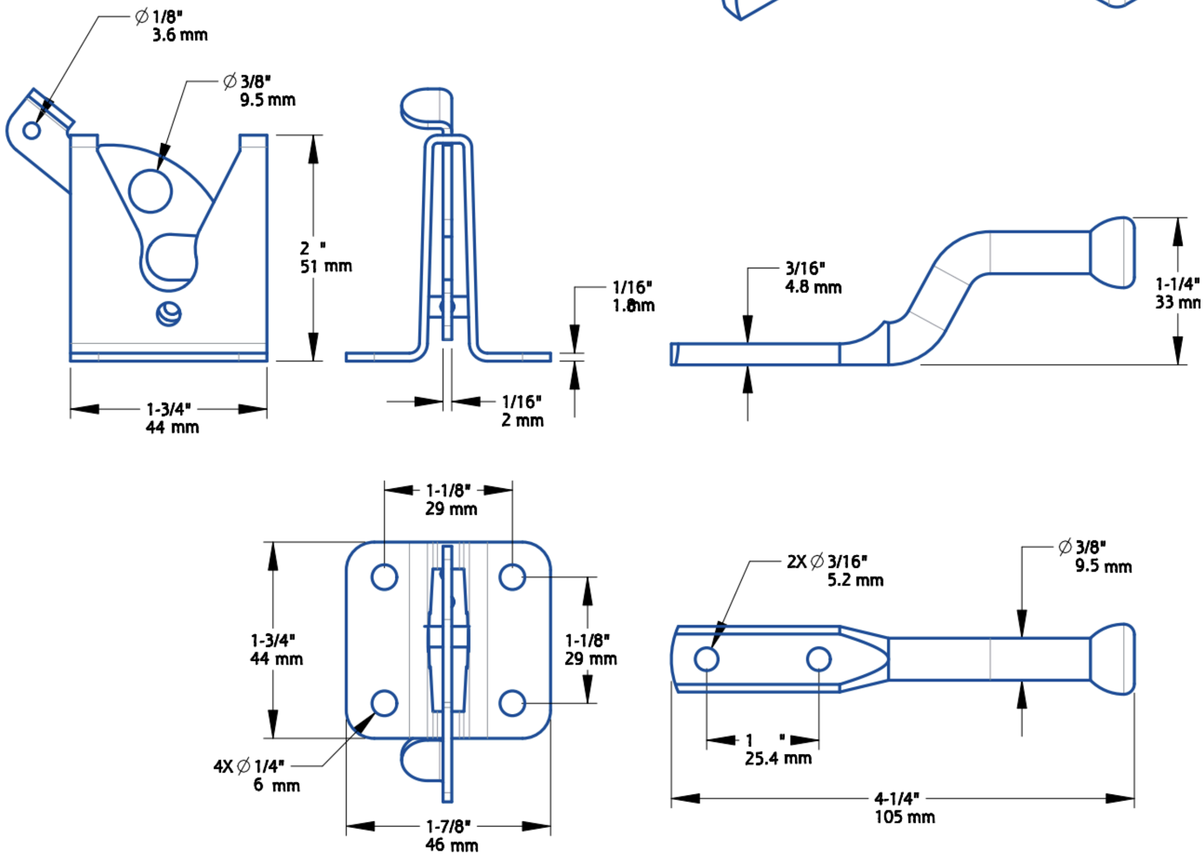
Dimensions of our proposed design concept



References Designs

Gravity Latch



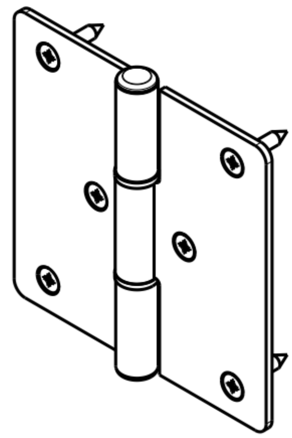


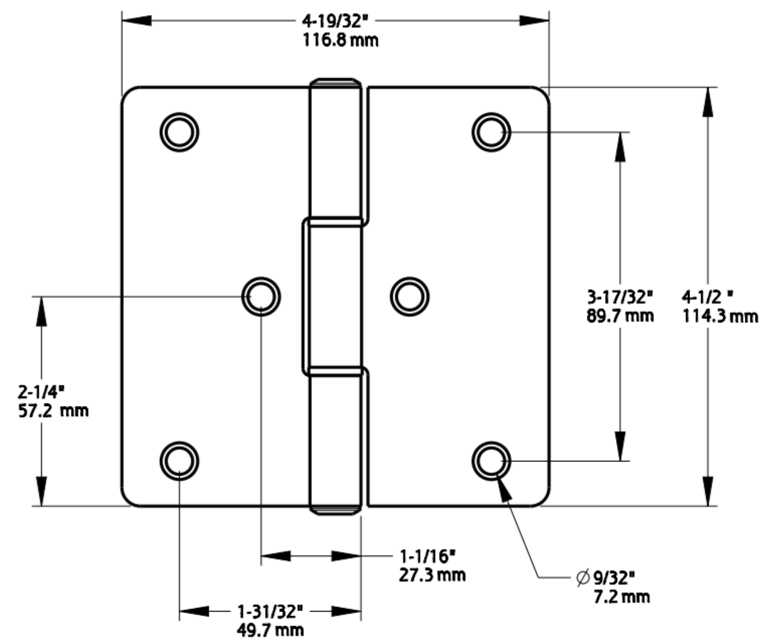
SKU	Family No.	Finish
N101-121	V21	Black
N101-162	V21	Zinc Plated
N262-121	V21	Galvanized
N262-105	V21	White
N184-861	BPB21	Black
N184-853	BPB21	Zinc Plated

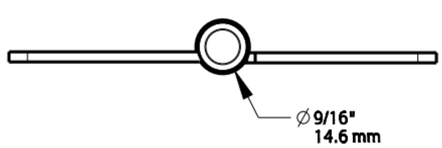
Material: Steel
Fasteners: (6) #10 X 1-1/4" PH Type AB Tapping Screw

https://nationalhardwarestorage.blob.core.windows.net/documents/nh_td_v29_v1261.pdf

Hinge







Fasteners: (6) #10 X 1" FH Type AB Tapping Screws
Material: Steel
Finish: Black

https://nationalhardwarestorage.blob.core.windows.net/documents/nh_td_v1106.pdf

Verification Trials

Test 1: Mode Button

Goal: Show that each button correctly changes the system mode.

Procedure:

1. Start System

2. Press each mode button (transition, playtime and clear)

3. Each mode sets mode to its respective mode

4. Repeat 5 times

Trial	Button Pressed	Expected Mode	Result	Pass/Fail
1-5	Transition	Transition	Transition	Pass
6-10	Playtime	Playtime	Playtime	Pass
11-15	Clear	Clear	Clear	Pass

```
System ready (starting in transition mode)
Mode = transition
Mode = transition
Mode = transition
Mode = transition
Mode = transition
Mode = play
Mode = play
Mode = play
Mode = play
Mode = play
Mode = clear
Mode = clear
Mode = clear
Mode = clear
Mode = clear
```

Test 2: Parent Button Functionality

Goal: Show that the system prevents opening in transition mode

Procedure:

1. Put system in different modes

2. Press Parent Button

3. For each mode watch how the servo acts against the parent button

4. Servo shall not turn in transition mode

5. Repeat for 5 trials for each mode

Trial	Mode	Servo Opened	Correctly Blocked	Pass/Fail
1-5	Transition	No	Yes	Pass
6-10	Playtime	Yes	Yes	Pass
11-15	Clear	Yes	Yes	Pass

```
System ready (starting in transition mode)
Parent pressed
Blocked (transition mode)
Mode = clear
Parent pressed
Opening
Mode = play
Gate opened detected
Vibration start
Gate closed -> waiting 3 seconds
Resetting to 0
Parent pressed
Opening
```

Test 3: Reed Switch Detection

Goal: Show that the reed switch accurately senses gate state and activates vibration

Procedure:

1. Put system to play mode
2. Keep gate closed initially
3. Open gate (Vibration expected)
4. Close gate (Vibration stopping expected)
5. Open gate and wait (Vibration shall stop after 5 seconds)
6. Repeat for 5 trials

Acceptance Range: 2.5s-3.5s to account for human error

Trial	**Open Gate Result**	**Close Gate Result**	**Vibration Stoppage Time**	**Pass/Fail**
1	Vibration	No Vibration	5.40	Pass
2	Vibration	No Vibration	3.25	Pass
3	Vibration	No Vibration	2.95	Pass
4	Vibration	No Vibration	2.88	Pass
5	Vibration	No Vibration	2.93	Pass

```
Opening
Gate opened detected
Vibration start
Gate closed -> waiting 3 seconds
Resetting to 0
Parent pressed
Opening
Gate opened detected
Vibration start
Gate closed -> waiting 3 seconds
Resetting to 0
Parent pressed
Opening
Gate opened detected
Vibration start
Gate closed -> waiting 3 seconds
Resetting to 0
Parent pressed
Opening
Gate opened detected
Vibration start
Gate closed -> waiting 3 seconds
Resetting to 0
Parent pressed
Opening
Gate opened detected
Vibration start
Gate closed -> waiting 3 seconds
Resetting to 0
```

Test 4: No Vibration in Clear mode

Goal: Show that clear mode suppresses the alert

Procedure:

1. Put system in clear mode

2. Open gate (No vibration expected)

3. Repeat for 5 trials

Trial	**Open gate**	**Pass/Fail**
1-5	No vibration	Pass

```
System ready (starting in transition mode)
Mode = clear
```

Test 5: Auto reset after gate closes for 3 seconds

Goal: Show that after opening, the servo only resets once the gate has been open for 3 seconds.

Procedure:

1. Put system to play mode
2. Press parent button to open gate
3. Open gate physically
4. Close gate physically
5. Start timer when gate closes
6. Measure time when servo closes
7. Repeat for 5 trials

Acceptance Range: 2.5s-3.5s to account for human error

Trial	Servo Reset Time	Within range?	Pass/Fail
1	3.21	Yes	Pass
2	2.95	Yes	Pass
3	3.13	Yes	Pass
4	2.99	Yes	Pass
5	3.23	Yes	Pass

```
System ready (starting in transition mode)
Mode = play
Parent pressed
Opening
Gate opened detected
Vibration start
Gate closed -> waiting 3 seconds
Resetting to 0
Parent pressed
Opening
Gate opened detected
Vibration start
Gate closed -> waiting 3 seconds
Resetting to 0
Parent pressed
Opening
Gate opened detected
Vibration start
Gate closed -> waiting 3 seconds
Resetting to 0
Parent pressed
Opening
Gate opened detected
Vibration start
Gate closed -> waiting 3 seconds
Resetting to 0
```