

INF2178 Assignment 2

Analysis of Space Utilization in Child Care Centers

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1 Introduction

Urban child care centers are essential, providing services critical for family support and contributing to the development of young minds. This study investigates how to better utilize the spaces within these centers to potentially enhance the quality of care and expand service capacity. Our attention is directed at understanding space utilization, considering spaces dedicated to infants under 18 months, toddlers between 18 to 30 months, preschoolers up to the age of entering grade one, children enrolled in full-day kindergarten, and school-age children beyond the first grade. Additionally, we assess the role of the centers' operational auspice—whether commercial, non-profit, or public—in influencing space utilization. Through this analysis, we anticipate offering insights to improve resource management and inform policy-making for child care centers.

2 Data and Methods

2.1 Data

The dataset encompasses operational details and capacity information from numerous licensed child care centers across Toronto, reflective of the conditions as of February 2024. To address the pressing issue of accessibility and affordability as highlighted by Toronto Children's Services, our dataset, titled 'INF2178_A2_data.xlsx', was meticulously compiled to include a diverse range of centers. These centers are demographically classified and provide services across multiple age groups, from infants to school-age children.

2.2 Statistical Approach

To analyze space utilization, we utilized one-way and two-way ANOVA tests, examining the influence of space type and operating auspice, respectively. Interaction effects were also assessed in the two-way ANOVA. Significant findings from ANOVA were further explored with Tukey's HSD post-hoc test. Assumptions of normality and homogeneity of variances were checked to ensure the validity of the ANOVA results, with data transformations applied where necessary.

2.3 Hypotheses

2.3.1 One-way ANOVA

For the analysis of space utilization across various child care settings, such as infant care spaces, toddler care spaces, preschool care spaces, kindergarten care spaces, and school-age child care spaces, we employed a one-way ANOVA. The formulated hypotheses were:

- Null Hypothesis (H_0):

$$\mu_{\text{infant}} = \mu_{\text{toddler}} = \mu_{\text{preschool}} = \mu_{\text{kindergarten}} = \mu_{\text{school-age}}$$

This hypothesis posits that the mean space utilization for infant, toddler, preschool, kindergarten, and school-age care spaces is identical across all categories.

- Alternative Hypothesis (H_a):

Not all mean space utilizations are equal, suggesting that at least one care space category has a different average utilization from the others.

2.3.2 Two-way ANOVA

- Null Hypothesis (H_0):

The mean space utilization value is the same for all operating auspices and for all types of child care spaces. There are no differences attributable to operating auspice or to the type of child care space.

Symbolically, this can be expressed as:

$$H_{0\text{auspice}} : \mu_{\text{Commercial}} = \mu_{\text{Non-Profit}} = \mu_{\text{Public}}$$

and

$$H_{0\text{space type}} : \mu_{\text{Infant}} = \mu_{\text{Toddler}} = \mu_{\text{Preschool}} = \mu_{\text{Kindergarten}} = \mu_{\text{School-Age}}$$

- Alternative Hypothesis (H_a):

There is at least one difference in mean space utilization value between the operating auspices and/or among the different types of child care spaces.

Symbolically, this can be expressed as:

$$H_{a\text{auspice}} : \text{At least one } \mu_{\text{auspice}} \text{ is different}$$

and

$$H_{a\text{space type}} : \text{At least one } \mu_{\text{space type}} \text{ is different}$$

3 Results

3.1 One-way ANOVA

The utilization of child care spaces was rigorously examined through a one-way ANOVA to determine if there were significant differences between space types, ranging from those for infants to school-age children. The results indicated significant variability in utilization values $F(4, 5310) = 188.190768, p < 0.001$ (Table 1), affirming that utilization is not consistently distributed across different space types.

Source	df	sum_sq	mean_sq	F	PR(>F)
C(space_type)	4	2.82×10^5	70 530.82	188.19	4.52×10^{-151}
Residual	5310	1.99×10^6	374.78	NaN	NaN

Table 1: ANOVA Table

A Tukey's HSD post-hoc test was conducted to delve deeper into the specific differences between space categories. This analysis revealed a significant disparity in utilization values between infant care spaces and toddler care spaces, with infants' spaces being utilized more on average by a difference of 70.370669

group1	group2	Diff	Lower	Upper	q-value	p-value
IGSPACE	TGSPACE	7.704	5.412	9.995	12.974	0.001
IGSPACE	PGSPACE	20.362	18.071	22.654	34.293	0.001
IGSPACE	KGSPACE	10.361	8.070	12.653	17.450	0.001
IGSPACE	SGSPACE	17.765	15.473	20.056	29.918	0.001
TGSPACE	PGSPACE	12.659	10.367	14.950	21.319	0.001
TGSPACE	KGSPACE	2.658	0.366	4.949	4.476	0.014
TGSPACE	SGSPACE	10.061	7.770	12.353	16.944	0.001
PGSPACE	KGSPACE	10.001	7.710	12.292	16.843	0.001
PGSPACE	SGSPACE	2.597	0.306	4.889	4.374	0.017
KGSPACE	SGSPACE	7.404	5.112	9.695	12.469	0.001

Table 2: Tukey’s HSD Post-Hoc Test

units $p < 0.001$ (Table 2). This pattern of significant variation persisted across all pairs of space types, underscoring a non-uniform utilization across the different age groups catered to by these spaces.

Discrepancies from normality were observed in the distribution of residuals, as indicated by the quantile-quantile (Q-Q) plot (Figure 1 and Figure 2), particularly at the distribution’s tails. This suggests the presence of outliers or a potential non-normal distribution. The histogram of residuals supported this observation, exhibiting a rightward skew.

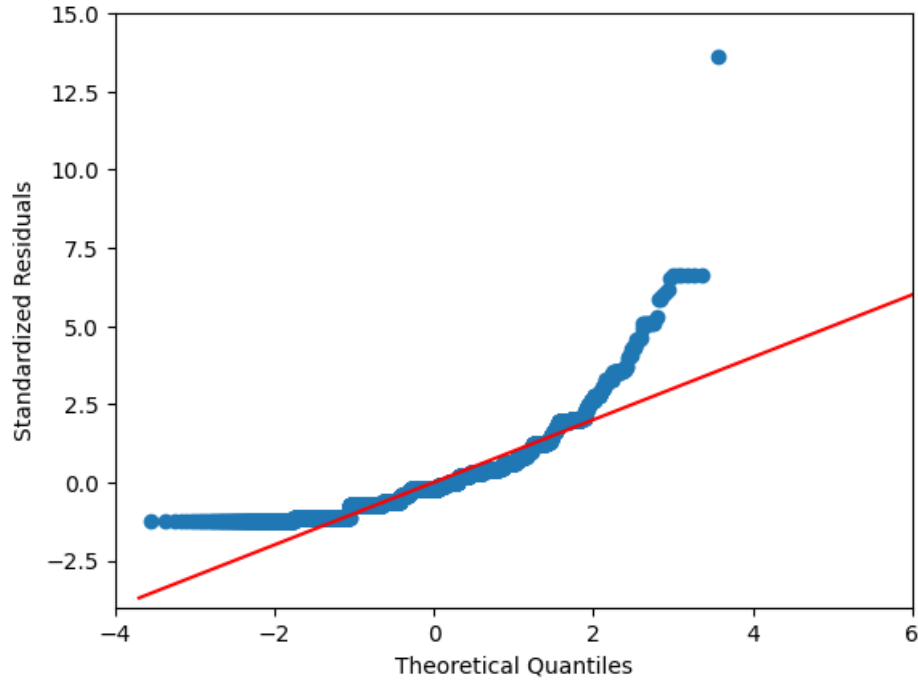


Figure 1: Q-Q Plot of Standardized Residuals

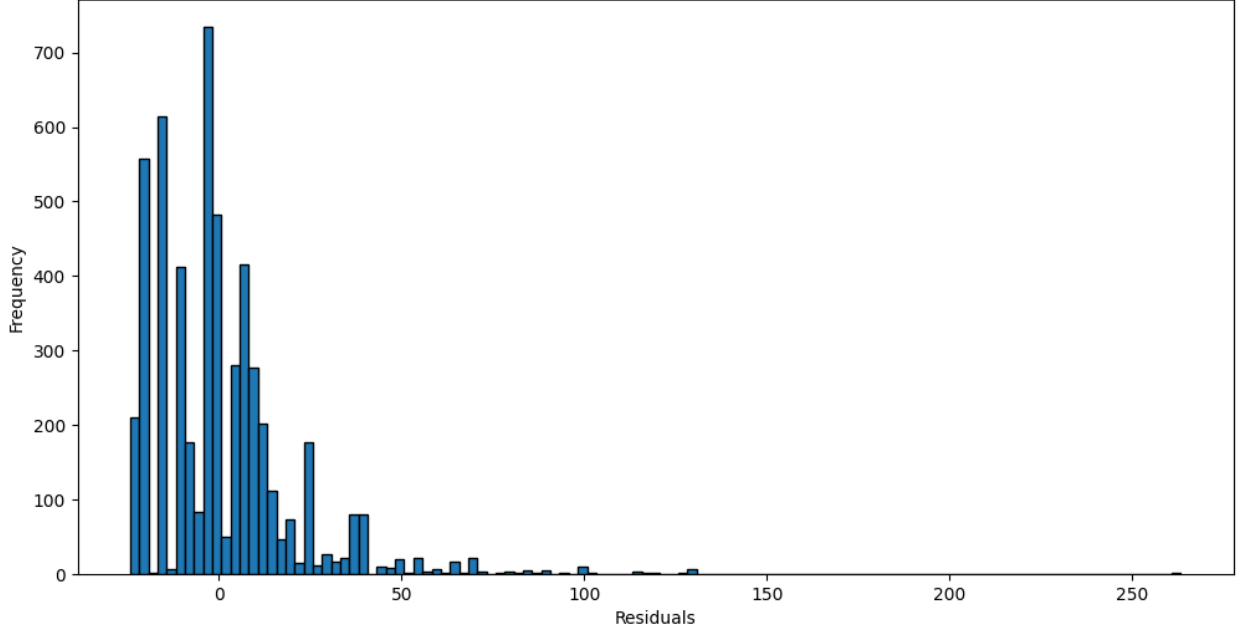


Figure 2: Histogram of Residuals

The Shapiro-Wilk test substantiated the non-normality of residuals $W = 0.842, p < 0.001$, while Bartlett’s test confirmed a significant difference in variances across the space types $T = 2461.736, p < 0.001$ (Table 3a), pointing to unequal variances. Similarly, Levene’s test also indicated that the assumption of homogeneity of variances was violated $W = 142.6228, p < 0.001$ (Table 3b).

Parameter	Value	Parameter	Value
Test statistics (T)	2461.736	Test statistics (W)	142.623
Degrees of freedom (Df)	4	Degrees of freedom (Df)	4
P-value	< 0.001	P-value	< 0.001

(a) Bartlett’s Test
(b) Levene’s Test

Table 3: Results of Statistical Tests

These findings regarding the assumptions of ANOVA—both the Shapiro-Wilk and Levene’s test results—highlight potential concerns in the ANOVA model’s assumptions. Given the large sample size, the one-way ANOVA’s robustness may accommodate some of these concerns. However, the presence of significant assumption violations calls for a cautious interpretation of the ANOVA results. Future analyses could consider data transformations or alternative methods such as non-parametric tests to account for these violations.

3.2 Two-way ANOVA

Our analysis sought to determine how different management types of child care centers—Commercial, Non-Profit, or Public—interact with the space designated for varying age groups, from infants to school-age children, to affect utilization. The two-way ANOVA unearthed significant independent effects of both management type $F(2, 5300) = 29.104369, p < 0.001$ and care area $F(4, 5300) = 213.579208, p < 0.001$ on how spaces were used (Table 4).

Source	sum_sq	df	F	PR(>F)
C(AUSPICE)	1.92×10^4	2	29.10	2.69×10^{-13}
C(space_type)	2.82×10^5	4	213.58	3.73×10^{-170}
C(AUSPICE):C(space_type)	2.21×10^5	8	83.52	9.97×10^{-131}
Residual	1.75×10^6	5300	NaN	NaN

Table 4: Two-Way ANOVA Table

The interaction between these two factors was also significant $F(8, 5300) = 83.519093, p < 0.001$ (Table 5), revealing that the type of care area is utilized differently depending on the center’s management structure. Interaction plots (Figure 3) supported this finding, showing distinct patterns of space usage. For instance, Non-Profit centers had the highest utilization in toddler spaces, whereas Commercial centers saw greater use in preschool areas. Public agencies were more balanced, except for a notable preference in infant spaces.

Source	df	sum_sq	mean_sq	F	PR(>F)
C(AUSPICE)	2	1.92×10^4	9611.21	29.10	2.69×10^{-13}
C(space_type)	4	2.82×10^5	70530.82	213.58	3.73×10^{-170}
C(AUSPICE):C(space_type)	8	2.21×10^5	27580.73	83.52	9.97×10^{-131}
Residual	5300	1.75×10^6	330.23	NaN	NaN

Table 5: Two-Way ANOVA Results

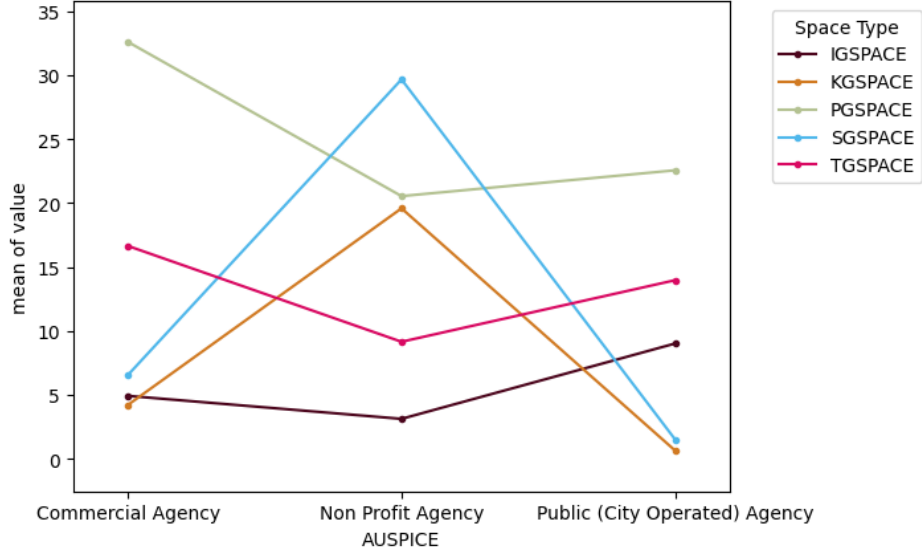


Figure 3: Interaction plot showing the mean of value for different space types across management types.

Furthermore, our post-hoc analysis using Tukey’s HSD test highlighted significant disparities between management types, with Non-Profit agencies using spaces differently compared to Commercial and Public agencies by various magnitudes (Table 6). For example, Non-Profit and Commercial agencies differed in space utilization by an average of 3.42 units $p = 0.001$, a variance that suggests different operational strategies in resource allocation.

group1	group2	Diff	Lower	Upper	q-value	p-value
Non Profit Agency	Commercial Agency	3.424	2.140	4.707	8.485	0.001
Non Profit Agency	Public(City Operated) Agency	6.867	3.733	10.001	7.264	0.001
Commercial Agency	Public(City Operated) Agency	3.443	0.212	6.674	3.533	0.033

Table 6: Comparison of Agency Types

The differences in space utilization across care areas within Non-Profit agencies were particularly marked (Table 7). Infant care spaces were utilized more compared to all other space types within these agencies, with differences ranging from 6.02 to 26.53 units, all significant at $p < 0.001$. Interestingly, this pattern did not hold when comparing Non-Profit to Commercial agencies for infant spaces, suggesting that the infant care spaces’ utilization patterns are comparable regardless of these two management types.

group1	group2	Diff	Lower	Upper	q-value	p-value
IGSPACE	TGSPACE	7.704	5.553	9.855	13.821	0.001
IGSPACE	PGSPACE	20.362	18.211	22.513	36.533	0.001
IGSPACE	KGSPACE	10.361	8.210	12.512	18.590	0.001
IGSPACE	SGSPACE	17.765	15.614	19.157	31.873	0.001
TGSPACE	PGSPACE	12.659	10.508	14.809	22.711	0.001
TGSPACE	KGSPACE	2.658	0.507	4.808	4.768	0.007
TGSPACE	SGSPACE	10.061	7.910	12.212	18.051	0.001
PGSPACE	KGSPACE	10.001	7.850	12.152	17.943	0.001
PGSPACE	SGSPACE	2.597	0.447	4.748	4.660	0.009
KGSPACE	SGSPACE	7.404	5.253	9.554	13.283	0.001

Table 7: Tukey’s HSD post-hoc test results

This comprehensive exploration into space utilization not only affirms the need for specialized management strategies across different care areas but also highlights the intricate relationship between space type and management model. These findings are critical for informing resource distribution and operational planning in child care centers, ensuring each age group’s needs are adequately met.

4 Conclusion

This investigation into child care center space utilization across different management types and age-specific areas revealed clear disparities. The statistical analysis highlighted that space usage varies significantly with management type and the particular care area, necessitating tailored management strategies. Infant spaces in non-profit centers, for instance, are notably different in utilization compared to other spaces.

The implication is clear: there is no one-size-fits-all solution in managing child care spaces. To optimize care and meet diverse needs, child care centers must adopt adaptable and informed approaches to space allocation. By doing so, they can enhance the quality of care provided to families and better support early childhood development.

In essence, our study calls for responsive and data-informed strategies in child care center operations to ensure efficient use of spaces and the well-being of children in urban environments.