UBC Classroom space allocation: Optimizing building selections

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Overview

The University of British Columbia, founded in 1908 has since become one of the leading universities in Canada and has gained international recognition for its academic excellence, cutting-edge research, and diverse student community. The university offers a wide range of undergraduate and graduate programs across its two main campuses: Vancouver and Okanagan, home to a combined 72,281 students (2021/22). This paper aims to find the optimal room allocation for students subject to UBC's max seating capacity. We admit that since UBC has a higher population than seating capacity, the optimal value will be that of the seating capacity. Meaning, there will not be much use of the optimal value, but there will be use of the optimized variables.

Dataset

Since UBC is such a big institution that spreads over two cities, this paper will only be using data relating to UBC Vancouver (i.e. UBC Vancouver student population and buildings) and will combine all majors into their respective faculties to reduce the amount of variables used. This paper also groups all year-levels and undergraduate/graduate students into their respective faculties.

Students: 60,292 student (UBC Vancouver only)[3]

Faculty	**2021 Winter**		
	Domestic	International	Total
Applied Science	5,307	2,755	8,062
Arts	11,318	5,509	16,827
Business	4,416	2,145	6,561
Dentistry	461	27	488
Education	4,147	458	4,605
Forestry	851	702	1,553
Postdoctoral	69	16	85
Land Systems	1,414	658	2,072

Law	630	70	700
Medicine	4,328	266	4,694
Pharmaceutical Sciences	1,077	43	1,120
Science	8,349	3,014	11,363
Vantage College	0	266	266
Non-Degree	1,121	775	1,896
Total	43,488	16,804	60,292

The UBC student year level per faculty is not public information on their yearly enrollment reports so the amount of students in different years in each faculty is an estimate in this paper. To find roughly how many students are in each year, their respective first year admission is used. For example, to find the rough amount of fourth years, the 1st year intake for 2018/19 is used, divided by the current UBC population. That proportion is then multiplied by each faculty's population for each year to get a rough estimate of how many students are in each faculty by year. Some faculties have certain year requirements to join (i.e. Dentistry has a requirement of three completed years or Education is a bachelors in any subject plus an eleven month program. The eleven month students will be under Graduate) which results in them not having any students in lower years. This will be calculated accordingly. Also, Postdoctoral students will be put into the Graduate student section. Here is the breakdown (if a student count ends up as a fraction, the ceil will be taken):

Faculty	First Year	Second Year	Third Year	Fourth Year	Graduate
Applied Science	1708	1764	1635	1434	1524
Arts	3564	3680	3412	2991	3181
Business	1390	1436	1331	1167	1241
Dentistry	0	0	0	241	247
Education	976	1008	934	819	871
Forestry	329	340	315	277	294
Postdoctoral	0	0	0	0	85
Land Systems	439	453	421	369	392
Law	0	0	0	0	700
Medicine	0	0	0	0	4694
Pharmaceutical Sciences	238	245	228	200	212
Science	2407	2486	2304	2020	2148
Vantage College	57	59	54	49	51
Total	10870	11471	10634	9567	15640

Rooms: 41 buildings (UBC Vancouver only)[4]

Code	Building Name	Capacity	Num. Rooms
AERL (x_1)	Aquatic Ecosystems Research Laboratory	144	1
ALRD (x_2)	Allard Hall	228	5
ANGU (x_3)	Henry Angus	1,545	28
ANSO (x_4)	Anthropology and Sociology	186	4
AUDX (x_5)	Auditorium Annex	41	2
BIOL (x_6)	Biological Sciences	394	4
BUCH (x_7)	Buchanan	3,130	60
CEME (x_8)	Civil and Mechanical Engineering	289	6
CHBE (x_9)	Chemical and Biological Engineering	354	3
CHEM (x_{10})	Chemistry	893	6
CIRS (x_{11})	Centre for Interactive Research on Sustainability	416	1

DMP (x_{12})	Dempster Hugh Pavilion	440	5
EOS (x_{13})	Earth and Ocean Sciences	50	1
ESB (x_{14})	Earth Sciences Building	580	3
FNH (x_{15})	Food, Nutrition and Health	263	5
FORW (x_{16})	Frank Forward	147	3
FRDM (x_{17})	Friedman Building	160	1
FSC (x_{18})	Forest Sciences Centre	633	9
GEOG (x_{19})	Geography	617	8
HEBB (x_{20})	Hebb	571	4
HENN (x_{21})	Hennings	581	6
IBLC (x_{22})	Irving K Barber Learning Centre	555	17
IONA (x_{23})	Iona Building	150	2
IRC (x_{24})	P.A. Woodward Instructional Resources Centre	1,296	16
LASR (x_{25})	Frederic Lasserre	264	5
LIFE (x_{26})	UBC Life Building	624	5
LSK (x_{27})	Leonard S. Klinck	505	4
MATH (x_{28})	Mathematics	495	7

MATX (x_{29})	Mathematics Annex	106	1
MCLD (x_{30})	Macleod	519	8
MCML (x_{31})	MacMillan	482	7
ORCH (x_{32})	Orchard Commons	662	21
OSB1 (x_{33})	Robert F. Osborne Centre	68	1
PCN (x_{34})	Ponderosa Commons North	240	8
PHRM (x_{35})	Pharmaceutical Sciences Building	479	3
SCRF (x_{36})	Neville Scarfe	1,019	19
SOWK (x_{37})	Jack Bell Building	190	6
SPPH (x_{38})	School of Population and Public Health	166	6
SWNG (x_{39})	West Mall Swing Space	1,605	26
UCEN (x_{40})	The Leon and Thea Koerner University Centre	163	4
WESB (x_{41})	Westbrook	427	2
Total		21,677	333

Math and Computations

Given that this paper is about space allocation with Linear programming, the math used will be Linear programming techniques, mainly the simplex method, to find a feasible region given n-constraints. From this, an optimization problem will be formed which will give an equation that will maximize the space-allocation with respect to the student population. Here the Linear programming problem will be:

$$maximize \sum_{i=1}^{41} c_i x_i \qquad subject\ to \sum_{j=1}^{41} a_{ij} \leq b_i$$

In our problem, the given variables are as follows: c_i is the room capacity and x_i is the respective rooms' building, a_{ij} is student year level, number of rooms and room capacity, and b_i is the constraints of a_{ij}. To compute this problem, this paper is using Python in JupyterLab with the PULP package[5]. Each building has been given a variable in the form of x_i. AERL, the first building in alphabetical order is x_1, ALRD is x_2 and so on. Furthermore, all variables must be positive since it is not possible to bound planes together on a feasibility graph that are less than 0. Given below are the equations to work with:

$$maximize$$

$$z = 144x_1 + 228x_2 + 1545x_3 + 186x_4 + 41x_5 + 394x_6 + 3130x_7 + 289x_8 + 354x_9 + 893x_{10} + 416x_{11} +$$

$$+ 440x_{12} + 50x_{13} + 580x_{14} + 263x_{15} + 147x_{16} + 160x_{17} + 633x_{18} + 617x_{19} + 571x_{20} + 581x_{21} + 555x_{22}$$

$$+ 150x_{23} + 1296x_{24} + 264x_{25} + 624x_{26} + 505x_{27} + 495x_{28} + 106x_{29} + 519x_{30} + 482x_{31} + 662x_{32} + 68x_{33}$$

$$240x_{34} + 479x_{35} + 1019x_{36} + 190x_{37} + 166x_{38} + 1605x_{39} + 163x_{40} + 427x_{41}$$

subject to

$$d_1 = 144x_1 + 228x_2 + 1545x_3 + 186x_4 + 41x_5 + 394x_6 + 3130x_7 + 289x_8 + 354x_9 + 893x_{10} + 416x_{11} + 440x_{12} + 50x_{13} + 580x_{14} + 263x_{15} + 147x_{16} + 160x_{17} + 633x_{18} + 617x_{19} + 571x_{20} + 581x_{21} + 555x_{22} + 150x_{23} + 1296x_{24} + 264x_{25} + 624x_{26} + 505x_{27} + 495x_{28} + 106x_{29} + 519x_{30} + 482x_{31} + 662x_{32} + 68x_{33} + 204x_{34} + 479x_{35} + 1019x_{36} + 190x_{37} + 166x_{38} + 1605x_{39} + 163x_{40} + 427x_{42} \leq 21677$$

$$d_2 = x_1 + 5x_2 + 28x_3 + 4x_4 + 2x_5 + 4x_6 + 60x_7 + 6x_8 + 3x_9 + 6x_{10} + x_{11} + 5x_{12} + x_{13} + 3x_{14} + 5x_{15} + 3x_{16} + x_{17} + 9x_{18} + 8x_{19} + 4x_{20} + 6x_{21} + 17x_{22} + 2x_{23} + 16x_{24} + 5x_{25} + 5x_{26} + 4x_{27} + 7x_{28} + x_{29} + 8x_{30} + 7x_{31} + 21x_{32} + x_{33} + 8x_{34} + 3x_{35} + 19x_{36} + 6x_{37} + 6x_{38} + 26x_{39} + 4x_{40} + 2x_{41} \leq 333$$

$$d_3 = 1708x_1 + 3564x_2 + 1390x_3 + 976x_5 + 329x_6 + 439x_7 + 238x_{11} + 2407x_{12} + 57x_{13} \leq 10870$$

$$d_4 = 1764x_1 + 3680x_2 + 1436x_3 + 1008x_5 + 340x_6 + 453x_7 + 245x_{11} + 2486x_{12} + 59x_{13} \leq 11471$$

$$d_5 = 1635x_1 + 3412x_2 + 1331x_3 + 934x_5 + 315x_6 + 421x_7 + 228x_{11} + 2304x_{12} + 54x_{13} \leq 10634$$

$$d_6 = 1434x_1 + 2991x_2 + 1167x_3 + 241x_4 + 819x_5 + 227x_6 + 369x_7 + 200x_{11} + 2020x_{12} + 49x_{13} \leq 9567$$

$$d_7 = 1524x_1 + 3181x_2 + 1241x_3 + 247x_4 + 871x_5 + 294x_6 + 85x_7 + 392x_8 + 700x_9 + 4694x_{10} + 212x_{11} + 2148x_{12} + 51x_{13} \leq 15640$$

$$x_1 \leq 1,\ x_2 \leq 5,\ x_3 \leq 28,\ x_4 \leq 4,\ x_5 \leq 2,\ x_6 \leq 4,\ x_7 \leq 60,\ x_8 \leq 6,\ x_9 \leq 3,\ x_{10} \leq 6,\ x_{11} \leq 1,\ x_{12} \leq 5,\ x_{13} \leq 1,\ x_{14} \leq 3,\ x_{15} \leq 5,\ x_{16} \leq 3,\ x_{17} \leq 1,\ x_{18} \leq 9,\ x_{19} \leq 8,\ x_{20} \leq 4,\ x_{21} \leq 6,\ x_{22} \leq 17,\ x_{23} \leq 2,\ x_{24} \leq 16,\ x_{25} \leq 5,\ x_{26} \leq 5,\ x_{27} \leq 4,\ x_{28} \leq 7,\ x_{29} \leq 1,\ x_{30} \leq 8,\ x_{31} \leq 7,\ x_{32} \leq 21,\ x_{33} \leq 1,\ x_{34} \leq 8,\ x_{35} \leq 3,\ x_{36} \leq 19,\ x_{37} \leq 6,\ x_{38} \leq 6,\ x_{39} \leq 26,\ x_{40} \leq 4,\ x_{41} \leq 2$$

$$x_1,\ x_2,\ \ldots,\ x_{41} \geq 0$$

d_1- Capacity of each building

d_2- Number of rooms in all buildings

d_3- First year students

d_4- Second year students

d_5- Third year students

d_6- Fourth year students

d_7- Graduate students

Sources of Error

The main source of error that may be relevant in this paper is from the dataset pertaining to how many students in each year level are in each faculty. This is because, as previously stated, that is not publicly accessible from UBC. In their yearly enrollment report, all that is available related to student numbers is how many students there are as a whole. In this paper, the way student year level was calculated was based on proportion. Students who should have been fourth year in the 2021W session may have dropped out before then or have not met promotion requirements. This leads to not true numbers in the dataset, so estimates need to be used, resulting in not-true values.

Results

After calculating everything in JupyterLab, here is a table of the optimal values for z:

Rooms used									
$x_{11} = 1$	$x_{14} = 3$	$x_{17} = 1$	$x_{18} = 4^*$	$x_{19} = 8$	$x_{21} = 6$	$x_{23} = 2$	$x_{27} = 4$	$x_{29} = 1$	$x_{41} = 1$
All other $x_i = 0$			*Rounded up to nearest whole number						

The optimal value is 21,677 rounded to the nearest whole number which is the total capacity of all buildings as expected. Since UBC's population is greater than UBC's seating capacity, the optimal value will just be the seating capacity. What we find from this is the optimal seating strategy. We observe that 1 room is used in CIRS, 3 rooms are used in ESB, 1 room is used in FRDM, 4 rooms are used in FSC, 8 rooms are used in GEOG, 6 rooms are used in HENN, 2 rooms are used in IONA, 4 rooms are used in LSK, 1 room is used in MATX, and 1 room is used in WESB. UBC combats this by not having all students have classes at the exact same time. This is why schedules are made and students have classes at different times throughout the week.

In conclusion, this paper has found the optimal room usage for UBC students. This can be used for future classroom developments as more rooms can be built that are in the same style as the optimal rooms, or the buildings with the optimal rooms can be expanded upon, both of which could further maximize room usage/allocation for UBC students – leading to more students and bright minds being able to join the UBC community, and further research and development in all areas of study.

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