What is the maximum number of people that could survive on earth? - Edward V

The world's population is currently just over 8 billion people, and has been on a rapid increase for centuries, meaning it will only continue to rise and rise for the next few centuries to come. The problem however is a few simple questions: What if the population gets too high? What do we do when we can't provide enough food for everyone to live off of? What do we do if we can't build enough housing for everyone to survive in? From a mathematical viewpoint, all of these questions simply come down to the way we use earth and how we optimise our land use, i.e. how much land we use for housing, infrastructure, transport and so on, there must be a so called "ideal" model we can use to maximise the survival of humanity, which is what will be discussed throughout this essay.

In modern society there are 2 main things humans need in order to survive and live at their best:

- 1. Adequate food and water supplies(enough food and water to sustain everyone)
- 2. Good infrastructure(housing, hospitals, green space, transport links, etc)

Given this information, intuitively you would think that the best way to maximise Earth's population capacity would be to split Earth's total land mass into half and have a 50/50 split, so have half of the land for food supplies(farming, fishing, factories, etc.) and the other half for infrastructure. While this seems correct upon first glance, the main problem with this is that it wouldn't be exactly optimal for human survival to use this ratio in practice, meaning in theory it would work in practice, but it wouldn't be exactly the hands down "best" solution, there are most certainly better splits that can be used to yield better results.

Earth has a total land area of approximately 149 million square kilometers, of which 70.8% being global oceans and the remaining 29.2% being solid land. This means that in order to optimise population size we have a total of 43,508,000 square kilometers to work with. It's also important to note that not exactly all of this landmass is ideal for use, for example, tall and steep mountains wouldn't be usable for housing or infrastructure. How much of the land can we use however? Well there's a few conditions the land needs to satisfy for us to be able to use it:

- 1. Needs a relatively flat gradient(Cannot be too steep)
- 2. Needs to be safe(Must have an environment safe for humans to inhabit)

With these conditions, we can eliminate the following areas:

- Any land that has an incline of 40 degrees or over to the horizontal (approximately 0.46% of Earth's land)
- Volcanoes and any land which is within 15km of a volcano(of which there being about 1500 land volcanoes)

- The exclusion zone around Chernobyl(due to nuclear fallout)
- Death Valley(USA), Antartica, Lut and Badain Jaran deserts(due to temperatures being too extreme)

Which we can then perform the following calculations on:

$Volcanoes$:

- $average\ volcano\ radius\ =\ 15km$
- $radius\ of\ total\ excluded\ area\ =\ 15\ +\ 15\ =\ 30km\ per\ volcano$
- $area\ per\ volcano\ =\ \pi\ \times\ 30^2\ =\ 900\pi$
- $total\ excluded\ volcano\ area\ =\ 1500\ \times\ 900\pi\ =\ 4,241,150.082km^2$

$steep\ land$:

- $43,508,000\ \times\ 0.0046\ =\ 200,136.8km^2$

$other\ regions$:

- $Exclusion\ Zone\ =\ \pi\ \times\ 30^2\ =\ 900\pi\ =\ 2,827.433388km^2$
- $Death\ Valley\ =\ 3.4\ million\ acres\ =\ 13,759.31184km^2$
- $Antartica\ +\ Lut\ +\ Badain\ Jaran\ =\ 14,200,000\ +\ 51,800\ +\ 49,200$
- $=\ 14,301,000km^2$

$\Rightarrow total\ inhabitable\ area\ =\ 43,508,000\ -\ 14,301,000\ -\ 13,759.31184\ -\ 2,827.433388$
$-\ 200,136.8\ -\ 4,241,150.082\ =\ 24,749,126.37km^2$

This means that we have a total of 24,749,126.37 square kilometres to use in order to maximise the population size, so now we need to find an ideal ratio we can partition the available land in to ensure maximum human capacity and survival.

The next thing we need to do is find approximate values for the following:

- 1. Minimum housing space per person
- 2. Average daily calories per person(and the corresponding land area required to provide this)
- 3. Infrastructure to population ratio (i.e. How much infrastructure must be built as the population varies)

Let's start with Minimum housing space per person. The smallest single-person apartments ever created are called Micro-apartments, which are typically found in crowded city areas such as New York City and San Francisco. Each Micro-apartment takes up around 100-400 square feet, and an average height of around 2.4 metres, which we can use to find the minimum volume per micro-apartment. Which we will use as the minimum housing space per person we require:

- $100\ square\ feet\ =\ 9.290304\ \times\ 10^{-6}km^2$
- $volume\ =\ (9.290304\ \times\ 10^{-6})\ \times\ 0.0024\ =\ 2.22967296\ \times\ 10^{-8}km^3/person$
- $\Rightarrow Minimum\ housing\ space\ per\ person\ =\ 2.23\ \times\ 10^{-8}km^3(3.s.f)$

It is also important that we use the minimum value as we are trying to maximise population size, and so we would want to minimise the living space per person in order to maximise space for more people, hence increasing the total population we can sustain.

Next, let's look at the amount of land required to provide a single person enough food daily. In 2022, around 37% of Earth's land was used for agriculture and food production. On top of this the world population in 2022 was approximately 8,021,407,192 people, so in order to find the land used per person to provide adequate nutrition we can perform the following calculation:

- $43,508,000 \times 0.37 = 16,097,960m^2$
- $land\ use\ per\ person = \frac{16,097,960}{8,021,407,192} = 2.006874806 \times 10^{-3} m^2/person$

Finally, we need to find the infrastructure to population ratio. The table below shows the number of patients the NHS received across England monthly from March 2025 up to February 2026:

England Level Data

	A&E attendances				Emergency Admissions							
Period	**Type 1 Departments - Major A&E**	**Type 2 Departments - Single Specialty**	**Type 3 Departments - Other A&E/Minor Injury Unit**	**Total Attendances**	**Emergency Admissions via Type 1 A&E**	**Emergency Admissions via Type 2 A&E**	**Emergency Admissions via Type 3 and 4 A&E**	**Total Emergency Admissions via A&E**	**Other Emergency Admissions (i.e not via A&E)**	**Total Emergency Admissions**	**Number of patients spending >4 hours from decision to admit to admission**	**Number of patients spending >12 hours from decision to admit to admission**
Mar-25	1,450,686	51,237	887,141	2,389,064	404,354	1,366	4,569	410,289	140,840	551,129	133,957	46,766
Apr-25	1,388,613	49,738	859,070	2,297,421	390,648	1,418	4,226	396,292	131,938	528,230	131,856	44,648
May-25	1,453,480	50,919	893,130	2,397,529	403,026	1,440	5,060	409,526	135,602	545,128	130,035	42,891
Jun-25	1,428,563	51,618	871,400	2,351,581	395,628	1,389	4,863	401,880	134,061	535,941	118,171	38,683
Jul-25	1,469,050	52,989	886,827	2,408,866	412,893	1,443	5,115	419,451	139,941	559,392	115,542	35,467
Aug-25	1,383,870	49,084	833,983	2,266,937	394,548	1,261	5,111	400,920	125,479	526,399	115,826	35,909
Sep-25	1,417,440	50,733	842,049	2,310,222	395,054	1,343	5,349	401,746	133,834	535,580	129,004	44,765
Oct-25	1,481,222	54,756	861,723	2,397,701	406,835	1,364	5,511	413,710	140,483	554,193	142,734	54,314
Nov-25	1,448,958	49,725	847,177	2,345,860	390,459	1,314	4,971	396,744	135,003	531,747	133,799	50,648
Dec-25	1,438,921	47,522	840,572	2,327,015	399,046	1,312	5,020	405,378	136,817	542,195	137,763	50,775
Jan-26	1,435,727	50,710	833,829	2,320,266	395,611	1,399	4,932	401,942	144,194	546,136	161,141	71,517
Feb-26	1,298,005	48,233	771,212	2,117,450	355,598	1,281	5,051	361,930	131,085	493,015	132,238	54,649

From this table we can calculate the total number of attendances within this time period:

- $total\ attendances = 2,389,064 + 2,297,421 + 2,397,529 +$ .....
- $\Rightarrow = 48,606,708\ attendances$

Furthermore, in the same time period the NHS had over 1,600 locations, taking up a total of 26,000,000 square metres, which we can use to calculate the Infrastructure to population ratio(I/P) we need:

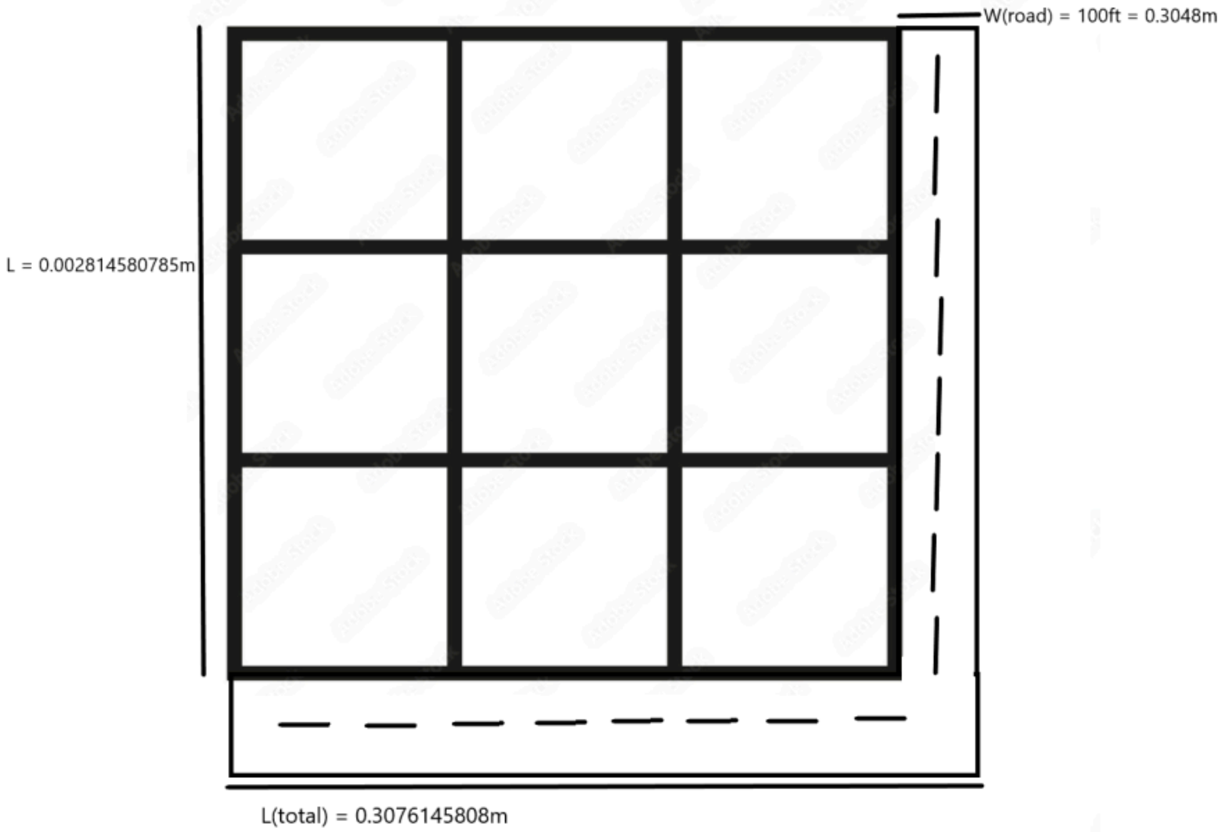
- $I/P = \frac{48,606,708}{26,000,000} = 1.869488769$
- $\Rightarrow I/P = 1.87\ m^2/person\ (3.s.f)$

Now just to quickly summarise, the previous few paragraphs have led to us obtaining the following information:

- $total\ inhabitable\ area = 24,749,126.37km^2$
- $minimum\ housing\ space\ per\ person = 2.22967296 \times 10^{-8} km^3/person$
- $food\ land\ use\ per\ person = 2.006874806 \times 10^{-3} m^2/person$
- $infrastructure\ to\ population\ ratio(I/P) = 1.869488769m^2/person$

The next problem we have to tackle is how to use these values to maximise the population size we can sustain in the long run.

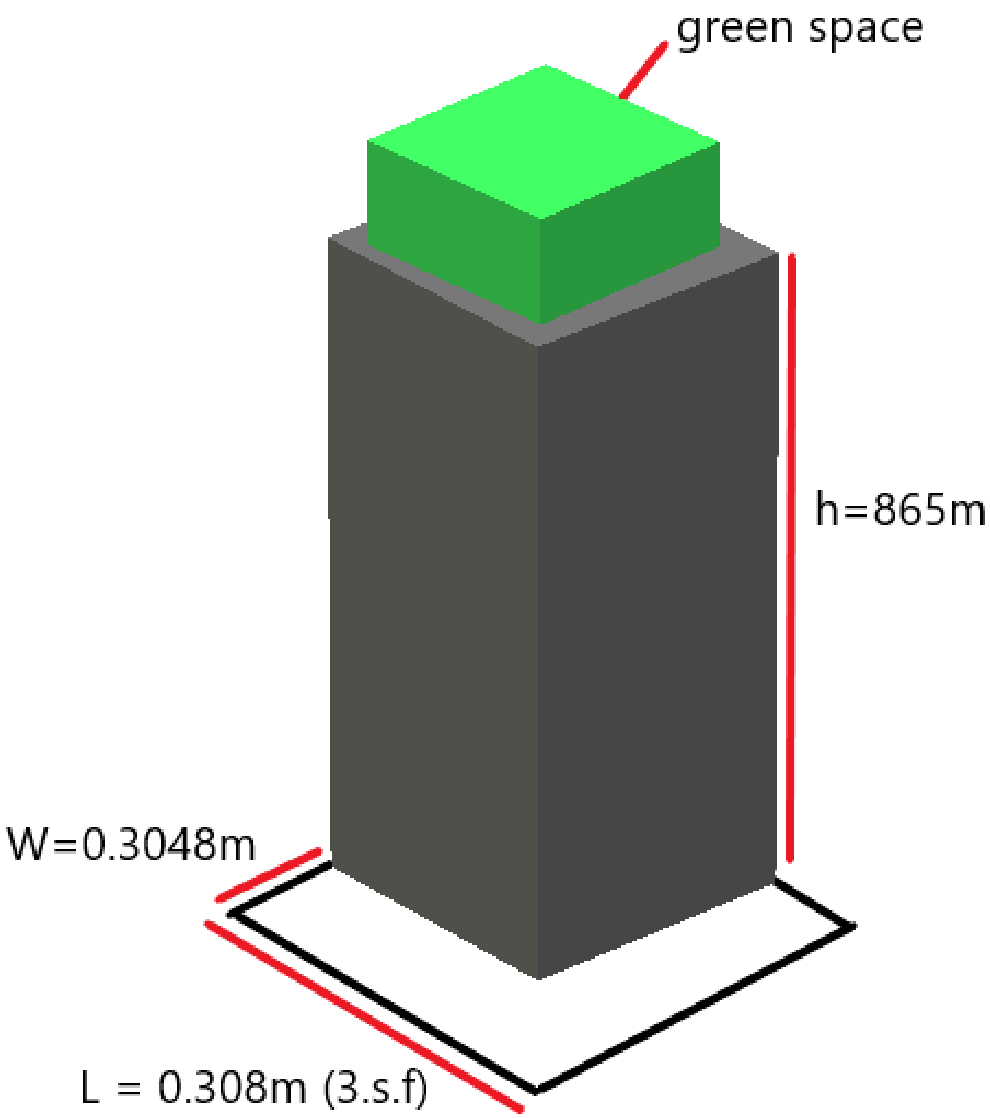
To do this we will arrange the housing spaces in “units”, which will essentially just be large columns of micro-apartments. Each of the units will consist of layers which will be 3x3 grids of micro-apartments as shown below:



This diagram also includes a 100ft (0.3048m) strip of road across 2 sides of the unit in order to account for transport infrastructure in between units. The road is only incorporated around 2 sides of the unit in order to avoid redundancy when the units are closely packed together, having loads of units interlocked together this way will allow for roads to be in between all the units while also minimising space use.

If we extend this idea to 3 dimensions however, we end up with each layer having the following properties:

- cross-sectional area = $7.1296785 \times 10^{-5} m^2$,
- height = $0.002814580785m$
- total volume = $2.00670566 \times 10^{-7} m^3$
- Roof area used for green space



Since plants can survive over 6,500 metres above sea level, the varying height they add to each unit will have no effect on any other calculated values(nothing will have to be changed for it to be incorporated), hence we won't have to include their height in any calculations.

Now moving onto the total height per unit. The tallest building in the world at the moment is the Burj Khalifa with a height of 828 metres. On top of this the deepest car park in the world is located under the Sydney Opera House and extends 37 metres below the ground.This means that if we were to have each unit go as deep underground and as high above ground as possible, it could theoretically have a height of 865 metres, hence each unit would contain around 307,328 micro-apartments and around 2.7 million people:

- $total\,volume = 865 \times (7.1296785 \times 10^{-5}) = 0.06167171903m^3$

- $no.\ layers\ = \frac{0.06167171903}{2.00670566\times10^{-7}} = 307,328.176$
- $total\,people\ =\ 307,328.176\ \times\ 9\ =\ 2,765,953\,people/unit$

Using the I/P value and the land use per person for food value calculated previously, we can find the infrastructure area needed per unit:

- $For\,infrastructure: 2,765,953\ \times\ 1.869488769\ =\ 5,170,918.069m^2/unit$
- $For\,food:\ 2,765,953\ \times\ (2.006874806\ \times\ 10^{-3})\ =\ 5,550.92139m^2/unit$

$This\,means\,that\,for\,every\,2,765,953\,people:$

- $Area\,per\,unit\ =\ (0.3076145808)^2 = 0.09462673032m^2$
- $Area\,per\,2,765,953\,people\ =\ (0.3076145808)^2\ +\ 5,170,918.069\ +\ 5,550.92139$
- $\Rightarrow = 5,176,469.085\ m^2/(2,765,953\,people)$
- $2,765,953\,people:\ 5,176,469.085m^2$

In order to calculate the absolute maximum population we can have with this information, we would have to get the land area use side of the ratio ($5,176,469.085m^2$) as close to the total inhabitable land value we calculated previously, which we can do with the following calculation:

- $total\,inhabitable\,area\ =\ 24,749,126.37km^2\ =\ 2.474912637\ \times\ 10^{13}m^2$
- $\frac{2.474912637\times10^{13}}{5,176,469.085} = 4,781,082.619$
- $2,765,953\ \times\ 4,781,082.619\ \ =\ 1.322424981\ \times\ 10^{13}people$
- $\Rightarrow Maximum\,population\ \ \approx\ \ 13,224,249,810,000\,people$

To conclude, If we were to use up all the possible land we can to maximise human population capacity, we would theoretically be able to sustain over 13 trillion people on Earth. While this calculated value does have a lot of inaccuracies such as:

- Not taking into account other transport methods(e.g. Planes, trains etc.)
- Not including areas of green space, leisure and so on.
- Rising sea levels reducing the amount of available land
- Land for energy sources, energy transfer methods etc.

The amount of land use for each of these factors is almost unpredictable due to their exponential, slow or random relationship with time(how they change with time), therefore the calculations would likely be unable to account for such factors. So if we were ever asked to estimate how large the population would be able to get on Earth alone, a smart value to say would be about 13 trillion.