

## Calculations and Context

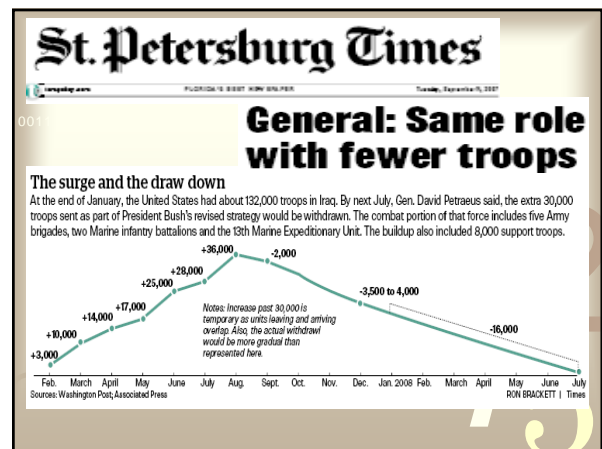
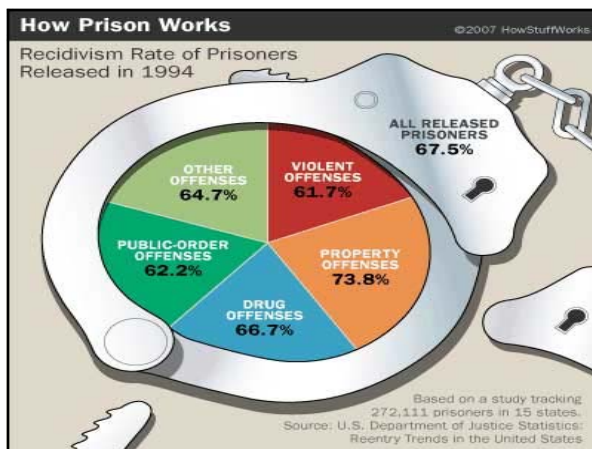
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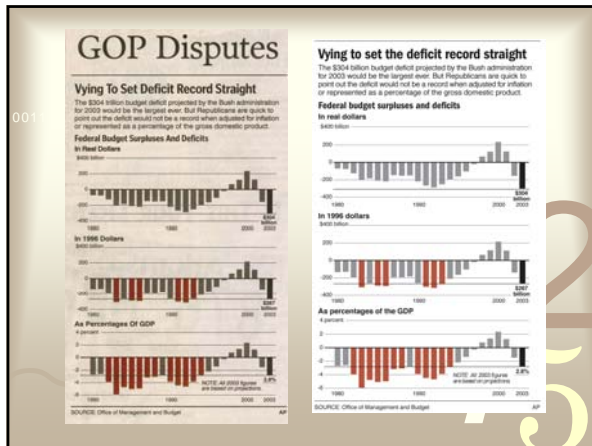
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**Bernie Madison**  
 – University of Arkansas

## Goals for Our Students

- **Critical consumers of numbers (quantities)**
  - Is it reasonable?
  - Is it unusual? How surprised should we be?
  - Is it correct?
  - Is it meaningful?
  - How was it determined?





### What \$1.2 Trillion Can Buy

The nation aimed to a very well-sung, to make record of a figure like \$1.2 trillion. The day's deal with a trillion-dollar budget deficit, and so when we come across such a big number, it's hard to digest it from the other side of the ledger.

#### One option is beating tanks into universal preschool.

Some could put a stop to the genocide in Darfur. All that would be one way to spend \$1.2 trillion. There would be another: The war in Iraq.

These estimates probably would have turned out to be too optimistic even if the war had gone well. Throughout history, people have typically overestimated the cost of war, as William H. Overholt, a Yale economics professor, notes.

But the deteriorating situation in Iraq has caused the actual problem to be left the mark by a side that is difficult to follow. The operation itself — the helicopters, the tanks, the fuel needed to run them, the cost of pay for military troops, the salaries of the contractors, the cost of the war in Iraq — is estimated to be \$100 billion a day, or \$36 billion a month, according to the Pentagon.

That translates into a couple of billions of dollars a week, over the last few years. And that's just the cost of the war, not the cost of reconstruction.

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For starters, \$1.2 trillion would pay for an unprecedented public health campaign — a doubling of cancer research funding, treatment for every American whose diabetes or heart disease is now going unmanaged and a global immunization campaign to save millions of children's lives.

Combined, the cost of running those programs for a decade wouldn't use up even half our money pot. So we could then turn to poverty and education, starting with universal preschool for every 3- and 4-year-old child across the country. The city of New Orleans could also receive a huge increase in reconstruction funds.

The final big chunk of the money could go to national security. The recommendations of the 9/11 Commission that have not been put in place — better baggage and cargo screening, stronger measures against nuclear proliferation — could be enacted. Financing for the war in Afghanistan could be increased to beat back the Taliban's recent gains, and a peacekeeping force could put a stop to the genocide in Darfur.

All that would be one way to spend \$1.2 trillion. Here would be another: The war in Iraq.

Ben Aron 10-30-07 (4)

The Shannon number,  $10^{10^8}$ , is an estimated lower bound on the game-tree complexity of chess, calculated by information theorist Claude Shannon as an aside in his 1950 paper "Programming a Computer for Playing Chess." Shannon notes:

With chess it is possible, in principle, to play a perfect game or construct a machine to do so as follows: One considers in a given position all possible moves, then all moves for the opponent, etc., to the end of the game (in each variation). The end must occur, by the rules of the game after a finite number of moves (remembering the 50 move drawing rule). Each of these variations ends in win, loss or draw. By working backward from the end one can determine whether there is a forced win, the position is a draw or is lost. It is easy to show, however, even with the high computing speed available in electronic calculators this computation is impractical. In typical chess positions there will be of the order of 30 legal moves. The number holds fairly constant until the game is nearly finished as shown [...] by De Groot, who averaged the number of legal moves in a large number of master games. Thus a move for White and then one for Black gives about 10<sup>3</sup> possibilities. A typical game lasts about 40 moves to resignation of one party. This is conservative for our calculation since the machine would calculate out to checkmate, not resignation. However, even at this figure there will be  $10^{10^8}$  variations to be calculated from the initial position. A machine operating at the rate of one variation per micro-second would require over 10<sup>8</sup> years to calculate the first move!

Shannon also estimated the number of possible positions, "of the general order of 64! / 32!(8!)<sup>21</sup>", or roughly  $10^{43}$ . This includes some illegal positions (e.g., pawns on the first rank, both kings in check) and excludes legal positions following captures and promotions. Taking these into account, Victor Allis calculated an upper bound of  $5 \times 10^{43}$  for the number of positions, and estimated the true number to be about  $10^{43}$ .

Allis also estimated the game-tree complexity to be at least  $10^{10^8}$ , "based on an average branching factor of 35 and an average game length of 89". As a comparison, the number of atoms in the Universe, to which it is often compared, is estimated to be between  $4 \times 10^{78}$  and  $10^{80}$ .

Suppose that you are trying to get a friend to understand the distance from Earth to the Moon in terms he/she understands well. What comparison would you use? For example, you might say, "If you could fly to the Moon at a constant speed of 1000 kilometers per hour, which is the speed of a fast passenger jet, it would take sixteen days to get there."

### Context matters!

The Legacy of Little Rock. Even today, 50 years later, the two schools are still socially separate and socially unequal.

89% Percentage of white students who attend schools that are more than 50% white

72% Percentage of black students who attend schools that are more than 50% minority

Source: 2005 study by the National Center for Education Statistics

**NUMBERS**

**CHILD MORTALITY**  
**9.7 million**  
 Number of children under age 5 who died in 2006 worldwide—a record low, down from almost 13 million in 1990

**19%**  
 Percentage of children under age 5 who died of pneumonia between 2000 and 2003. Undernutrition is the root cause of 53% of deaths in that age group

**GAY RIGHTS**  
**195**  
 Number of major U.S. businesses that earned the highest score in the Corporate Equality Index, a Human Rights Campaign metric that rates how employers treat lesbian, gay, bisexual and transgender employees on a scale of 0 to 100. FedEx, Yahoo! and MasterCard were among the companies that received top marks

**13**  
 Number of businesses that received the top rating when the index was first released, in 2002

**MOTORCYCLES**  
**10%**  
 Percentage of motorcyclists in the U.S. who are female. Women make up the fastest-growing segment in the \$9.7 billion industry

**41**  
 Average age of motorcyclists today, up from 32 in 1990

**SKYSCRAPERS**  
**2,625**  
 Expected height in feet (800 m) of the Burj Dubai, a hotel, business and residential complex under construction in the United Arab Emirates. It just surpassed the CN Tower in Toronto, which stands at 1,814 ft. (553 m), as the world's tallest freestanding structure

**\$4.1 billion**  
 Cost of the Burj Dubai. Workers have already completed 145 of 165 floors, working at a pace of one floor every three days

Sources: STATISTICA (2); Human Rights Campaign Foundation (2); Reuters (2); CNN (2)  
 TIME: October 1, 2007

**NIGERIA**  
**\$5 million**  
 Estimated worth of the new President of Nigeria, Umaru Yar'Adua. Most of his wealth was inherited. He publicly declared his assets, an unusual move, in an effort to increase transparency

**70 million**  
 Estimated number of Nigerians who live on less than \$1 a day

*We are invited to compare a wealthy ruler with the poverty of the ruled...*

Sources: BBC (2); USA Today (1); BBC; Portelligent; BBC; Reuters  
 TIME July 16, 2007

Context matters...

**\$16 billion**  
 Estimated worth of Alice Walton.

**300 million**  
 Estimated number of Americans who live on less than \$3200 per day?

Proportional thinking: \$16 billion is 3200 times \$5 million, and \$3200 is 3200 times \$1.

Contexts can be Distracting

Morning Edition, April 30, 2008:

*"Beijing is pledging a tobacco-free Olympics, and as part of that promise, the city will expand its existing smoking ban in certain public areas Thursday. But past government smoking bans have been widely ignored."*

*"China is the world's largest consumer of tobacco products." [story]*

NPR's "spin": It is ironic that the largest consumer of tobacco products is trying to implement a tobacco ban.

1. What is meant by "largest"?
2. What should be meant by "largest"?

3. Why did a respectable news agency fail to take into account China's population?
4. Does this detract from the rest of the story?

- Moral: Good reporting can be undermined by failing to take into account the numeracy of the audience.
- Brief Aside: National Geographic used a "poor graph" in an article presenting an argument for the human factor in global warming/climate change.

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45

### Back of the Envelope Calculations

- Using data found at WHO
  - Maybe 23% of Chinese population smokes?
  - Maybe 35% of Chinese smoke?
  - Population of China: 1.3 billion.
  - → # Chinese smokers: 300-455 million.
  - 20% of Americans smoke
  - Population of US: 300 million.
  - → # of US smokers: 60 million

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### Goals for Our Students

Careful and effective users of numbers

- Quantitative arguments
- Assessing risk
- Measuring change

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### Goals for Our Students

Important numbers  
- 65

What are the chances that someone in our audience has a birthday today and is turning 65?

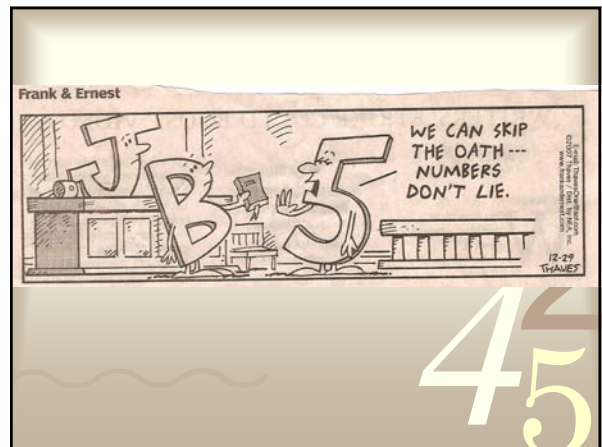
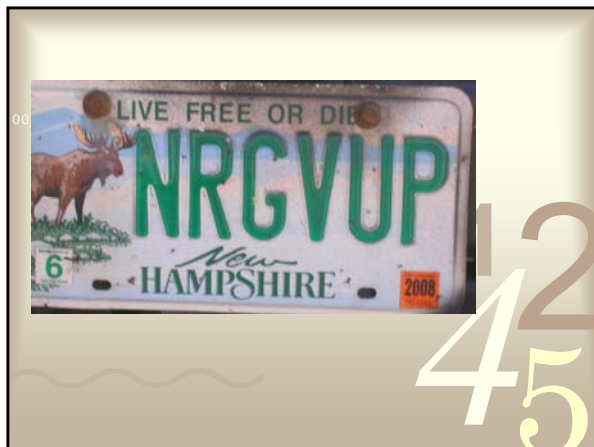
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	2001	2002	2003	2004
U.S. Troop Fatalities	86	85	90	83
U.S. Troops Wounded	151	491	608	641
Iraq Security Force Fatalities	65	85	282	233
Iraq Civilian Deaths From Violence	700	1,500	2,000	3,000
Multi-Fatality Bombings	4	13	27	52
Foreigners Kidnapped	0	30	24	0
Internally Displaced Persons (since April 2003)	100,000	200,000	250,000	500,000
Attacks on Oil Assets	5	21	9	2
U.S./Other Coalition Troops in Iraq (in thousands)	135/22	140/24	138/23	140/19

Iraq Security Forces in Top Two Breeding Years (end of year, in thousands)	0	0	30	100
Oil Production (in millions of barrels per day, average years 2000-02)	1.4	2.1	2.2	2.2
Household and Transport Fuel Supplies (in millions of gallons per day)	87	94	96	21
Average Electricity Production (in megawatts per hour, 2000)	3,200	4,700	4,000	4,000
Trained Judges (estimated until 2003)	0	260	250	250
Registered Cars (in millions per year, 2000)	1.5	2.0	3.0	3.5
Children in School (in millions per year, 2000)	4.5	4.8	5.1	5.2
Iraqis Optimistic about Future (percent)	60	51	43	41

Nous Kamp is a senior research assistant at the Brookings Institution in Washington. Michael O'Hanlon is a senior fellow at Brookings and the co-author of "Hard Power." Amy Diefenderfer is a graphic designer in South Norwalk, Conn. Andrew Kuzma of Brookings assisted in reworking the chart.




Units matter....  
 001 .... a lot




### Smart


My dad gave me one dollar bill  
 'Cause I'm his smartest son,  
 And I swapped it for two shiny quarters  
 'Cause two is more than one!




And then I took the quarters  
 And traded them to Lou  
 For three dimes -- I guess he don't know  
 That three is more than two!




Just then, along came old blind Bates  
 And just 'cause he can't see  
 He gave me four nickels for my three dimes,  
 And four is more than three!



And I took the nickels to Hiram Coombs  
 Down at the seed-feed store,  
 And the fool gave me five pennies for them,  
 And five is more than four!



And then I went and showed my dad,  
 And he got red in the cheeks  
 And closed his eyes and shook his head--  
 Too proud of me to speak!



- Shel Silverstein