

# Game Design Math

Part 2: Game balancing

Aalto University, Game Analysis course

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# Why?

1. Math can give you a consistent and roughly correct initial guesses
  - Final solution then iterated through playtesting & A/B testing
2. A spreadsheet or a Colab notebook can make it easier to update many things at once
  - Change one number to get and visualize, e.g., new character stats for all levels
  - A game prototype with a single level does not need a spreadsheet and design by math, but defining values using math is basically a form of automation needed when the game is scaled up to multiple levels, characters, weapons etc.
  - Especially relevant in games as a service, where you need to model and predict how the game should evolve over years, with players feeling like they make progress, and an engaging experience provided for both old and new players



# Iain Compton:

“A lot of game design is done in an Excel sheet. As a rule of thumb, design starts in a text document and ends with a spreadsheet.

As a designer a lot of things are dependent on numbers. Experience points, damage, hit points, currency, etc. A lot of those have complex inter-relationships too. As a designer you will want to be able to model things before making balance changes. If you increase one number by a certain amount, how much does it affect a different number? How long does it take a player to go through your content? How much currency should a player have at a certain point in the game? And so on. You will need to be able to create reasonably complex algorithms that take several numbers from different systems and output a number that matches your design parameters. For example, in a shooter that I made, the player got an amount of XP and in-game currency after each match. Those rewards had to fall into a specific range of numbers but the inputs could be wildly different due to players of different skill levels, time spent in the match, etc. I had to create an algorithm that rewarded skill but didn't punish failure and that gave incentives for staying in the match to the end even for a team that was clearly outmatched. That is a pure maths problem.”



# A highly marketable skill

- Especially in F2P, knowing how to design and model game balance and economy can be crucial
- A final assignment from 2018 that landed Francesco Fontana his first game designer job at Wargaming Helsinki (shared with permission):  
[https://docs.google.com/spreadsheets/d/1ziuQmP2XTDIGUFvi\\_R6GIClitmbPm47wAVpb1pAq7do/edit#gid=1054610195](https://docs.google.com/spreadsheets/d/1ziuQmP2XTDIGUFvi_R6GIClitmbPm47wAVpb1pAq7do/edit#gid=1054610195)

Francesco has since worked at Rovio and is now a senior game designer at Savage Game Studios.

<b>Battlecry:</b> Summon a 1/1\_Murloc Scout.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	
1	NAME	CARD SET	TYPE	RARITY	TEXT	CLASS	MECHANICS	TYPE	HEALTH	ATTACK	REAL COST		BASIC COST	RAW GAME VALUE		RAW GAME VALUE (Basic Set Only)	
2	Starving Buzzard	Basic	Minion	Free	never you summon a Beast, draw a	Hunter		Beast	2	3	5		2.5	-2.5		-2.5	
3	Reckless Rocketeer	Basic	Minion	Free	<b>Charge</b>	Neutral	Charge		2	5	6		3.5	-2.5		-2.5	
4	Stormpike Commando	Basic	Minion	Free	<b>Battlecry:</b> Deal 2 damage.	Neutral	Battlecry		2	4	5		3	-2		-2	
5	Tundra Rhino	Basic	Minion	Free	Your Beasts have <b>Charge</b>.	Hunter	Charge	Beast	5	2	5		3.5	-1.5		-1.5	
6	Wolfriider	Basic	Minion	Free	<b>Charge</b>	Neutral	Charge		1	3	3		2	-1		-1	
7	Ironforge Rifleman	Basic	Minion	Free	<b>Battlecry:</b> Deal 1 damage.	Neutral	Battlecry		2	2	3		2	-1		-1	
8	Windspeaker	Basic	Minion	Free	y:</b> Give a friendly minion <b>Wi	Shaman	Windfury Battlecry		3	3	4		3	-1		-1	
9	Novice Engineer	Basic	Minion	Free	<b>Battlecry:</b> Draw a card.	Neutral	Battlecry		1	1	2		1	-1		-1	
10	Raid Leader	Basic	Minion	Free	Your other minions have +1 Attack.	Neutral	Aura		2	2	3		2	-1		-1	
11	Gnomish Inventor	Basic	Minion	Free	<b>Battlecry:</b> Draw a card.	Neutral	Battlecry		4	2	4		3	-1		-1	
12	Frostwolf Warlord	Basic	Minion	Free	n +1/+1 for each other friendly minio	Neutral	Battlecry		4	4	5		4	-1		-1	
13	Stormwind Champion	Basic	Minion	Free	Your other minions have +1/+1.	Neutral	Aura		6	6	7		6	-1		-1	
14	Bluegill Warrior	Basic	Minion	Free	<b>Charge</b>	Neutral	Charge	Murloc	1	2	2		1.5	-0.5		-0.5	
15	Silverback Patriarch	Basic	Minion	Free	<b>Taunt</b>	Neutral	Taunt	Beast	4	1	3		2.5	-0.5		-0.5	
16	Dalaran Mage	Basic	Minion	Free	<b>Spell Damage +1</b>	Neutral	Spell Damage		4	1	3		2.5	-0.5		-0.5	
17	Kor'kron Elite	Basic	Minion	Free	<b>Charge</b>	Warrior	Charge		3	4	4		3.5	-0.5		-0.5	
18	Stormwind Knight	Basic	Minion	Free	<b>Charge</b>	Neutral	Charge		5	2	4		3.5	-0.5		-0.5	
19	Botchy Bay Bodyguard	Basic	Minion	Free	<b>Taunt</b>	Neutral	Taunt		4	5	5		4.5	-0.5		-0.5	
20	Archmage	Basic	Minion	Free	<b>Spell Damage +1</b>	Neutral	Spell Damage		7	4	6		5.5	-0.5		-0.5	
21	Lord of the Arena	Basic	Minion	Free	<b>Taunt</b>	Neutral	Taunt		5	6	6		5.5	-0.5		-0.5	
22	Boar	Basic	Minion	Common		Neutral		Beast	1	1	1		1	0		0	
23	Sheep	Basic	Minion	Common		Neutral		Beast	1	1	1		1	0		0	
24	Murloc Scout	Basic	Minion	Common		Neutral		Murloc	1	1	1		1	0		0	
25	Skeleton	Basic	Minion	Common	<b></b>	Neutral			1	1	1		1	0		0	
26	Searing Totem	Basic	Minion	Free		Shaman		Totem	1	1	1		1	0		0	
27	Silver Hand Recruit	Basic	Minion	Free		Paladin			1	1	1		1	0		0	
28	Magma Rager	Basic	Minion	Free		Neutral		Elemental	1	5	3		3	0		0	
29	Core Hound	Basic	Minion	Free		Neutral		Beast	5	9	7		7	0		0	
30	War Golem	Basic	Minion	Free		Neutral			7	7	7		7	0		0	
31	Dragonling Mechanic	Basic	Minion	Free	y:</b> Summon a 2/1 Mechanical D	Neutral	Battlecry		4	2	4		3	-1		-1	
32	Nightblade	Basic	Minion	Free	ecry: </b>Deal 3 damage to the ene	Neutral	Battlecry		4	4	5		4	-1		-1	
33	Murloc Tidehunter	Basic	Minion	Free	ttlecry:</b> Summon a 1/1_Murloc	Neutral	Battlecry	Murloc	1	2	2		1.5	-0.5		-0.5	
34	Warsong Commander	Basic	Minion	Free	<b>Charge</b> minions have +1 Att	Warrior	Charge Aura		3	2	3		2.5	-0.5		-0.5	



# Francesco says (1 year after the course):

“If you want to be a game design for mobile AND console or PC, you need to have a good understanding of the things you're going to learn in this course. It's crucial, even if you don't want to do any system heavy games, 3/4 of the games have some sort of system that needs to be designed and then balanced. Even narrative-focused indie games like Amnesia have systems like health, oil for the lamp etc, and those systems need to be crafted. So, enjoy this course and try to get as much as possible out of it if you want to do some game design in the future. Regarding my experience, I was hired mainly because I was able to showcase some practical balancing knowledge from this course.”

## The job interview process

- - 4 interviews
- - 10% my life and studies
- - 60% "Hey, I've got this Hearthstone Analysis I did few months ago, do you wanna check it out?"
- - 30% discussions about games and why certain companies made some game design choices here and there.

## Job in practice:

- - 40% creating and balancing systems on google sheet and ensure that they can be implemented in the game with the current tools
- - 30% Designing features and writing detailed documentation about it
- - 30% define detailed UX flows and user paths for each feature





# Game balancing

- Overall: determining the numbers/parameters of the game.
- Challenge level appropriate for the audience?
- Balance of starting positions?
- Balance of multiple strategies?
- Balance of objects such as cards, battle units?

# INTRODUCTION

- Stefan Engblom
- Game designer / Clash Royale / Supercell
- Balancing, economy, system design





# Three ways of balancing

- Use math and simulations (transitive and intransitive relationships)
- Use your design instincts
- Use playtesting
- Generally, a good idea to start with math if it's feasible







# Two main types of relations

- Transitive relationships: cost/benefit curves
- Intransitive relationships: rock-paper-scissors, every unit has both weaknesses and strengths, wins some but loses to others

# Balancing intransitive relationships

- Key principle: every attack must have a counter
- Rock-paper-scissors is balanced because every choice has equal opportunity of winning and losing

# Intransitive relationships in Clash Royale

			
		WIN	LOSE
	LOSE		WIN
	WIN	LOSE	

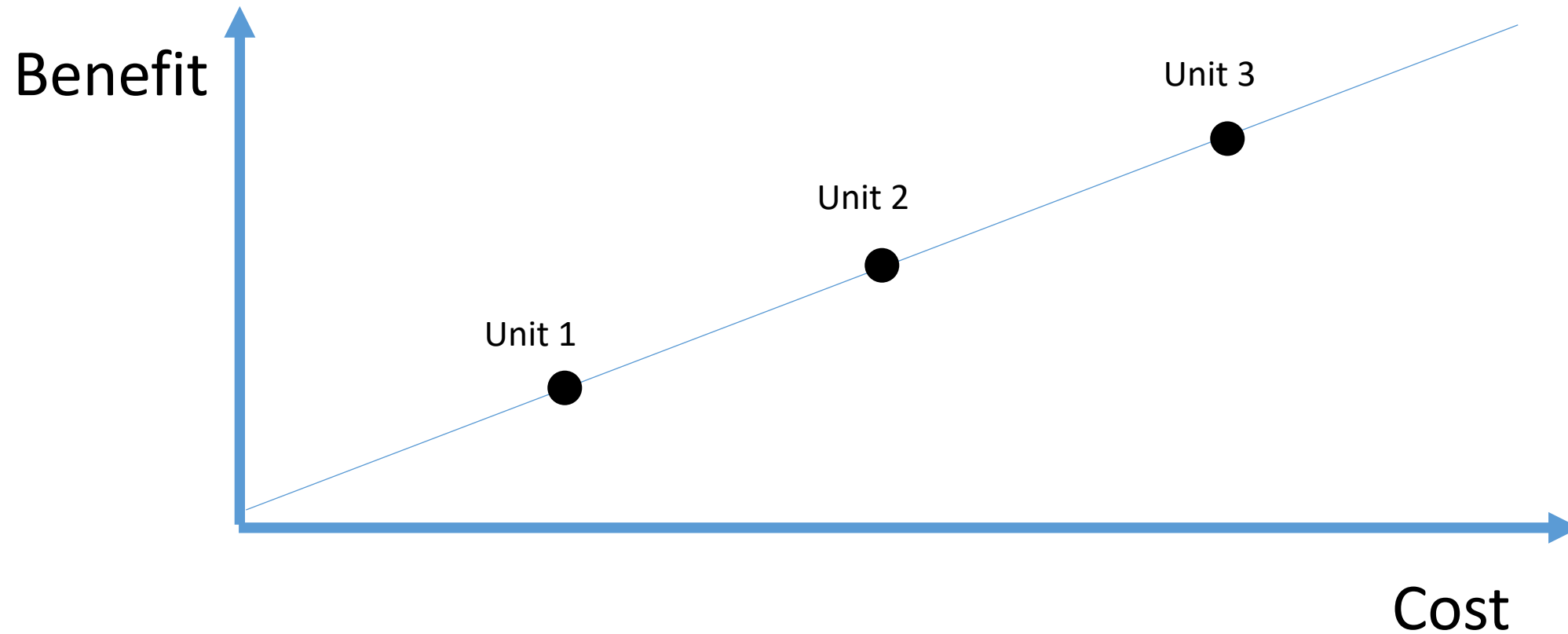


# Balancing transitive relationships

- Design based on "cost curves" – general relationships of variables such as item cost and item benefit (e.g., elixir cost vs. damage per second and hit points in Clash Royale)
- Rule of thumb: All units should have approximately equal cost/benefit ratio.
- Challenge: How to make at least some units feel very powerful at the same time?

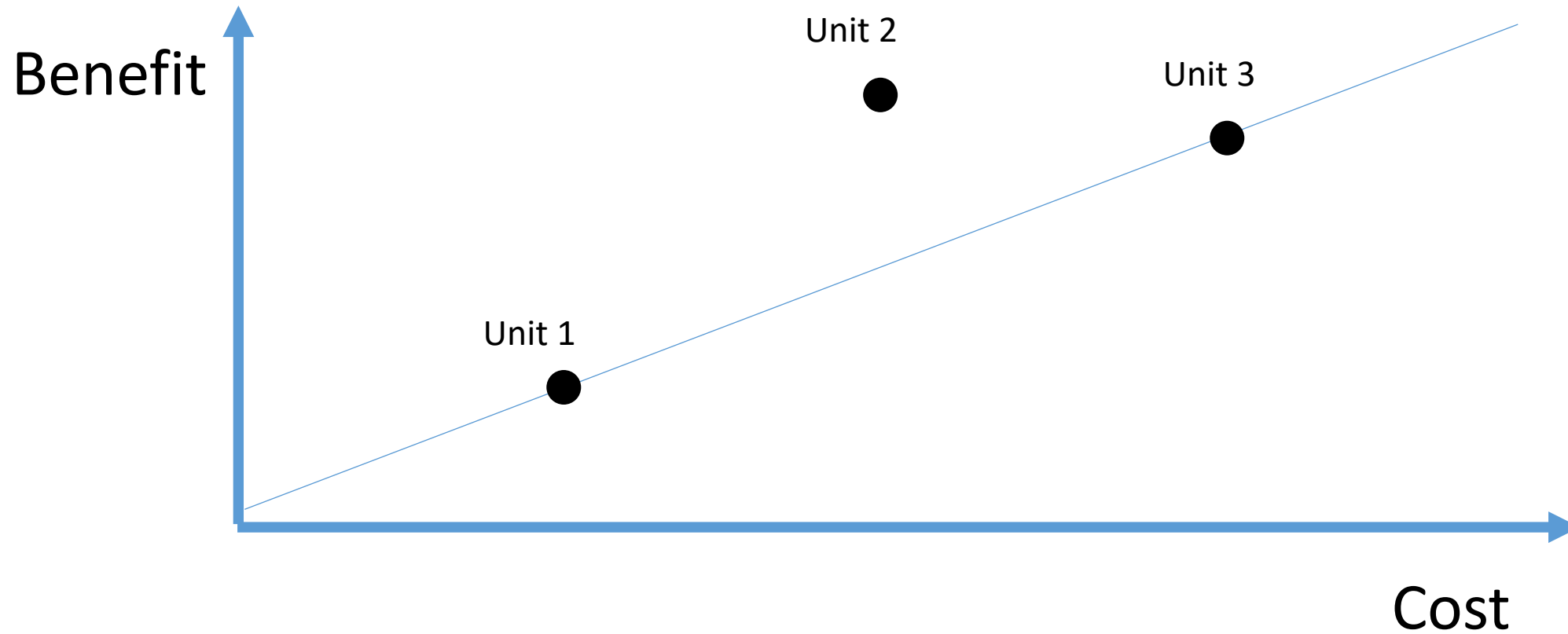


# Linear cost curve: a reasonable default



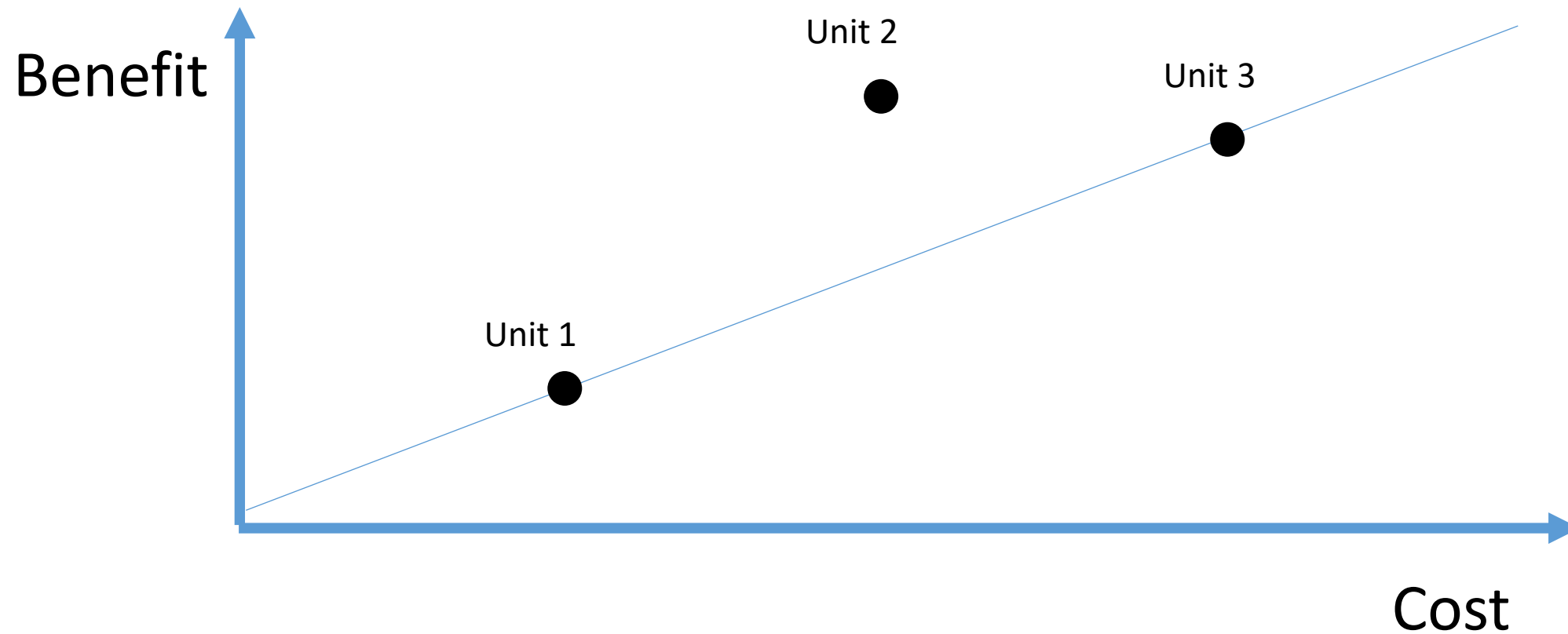


# Why is this not good?





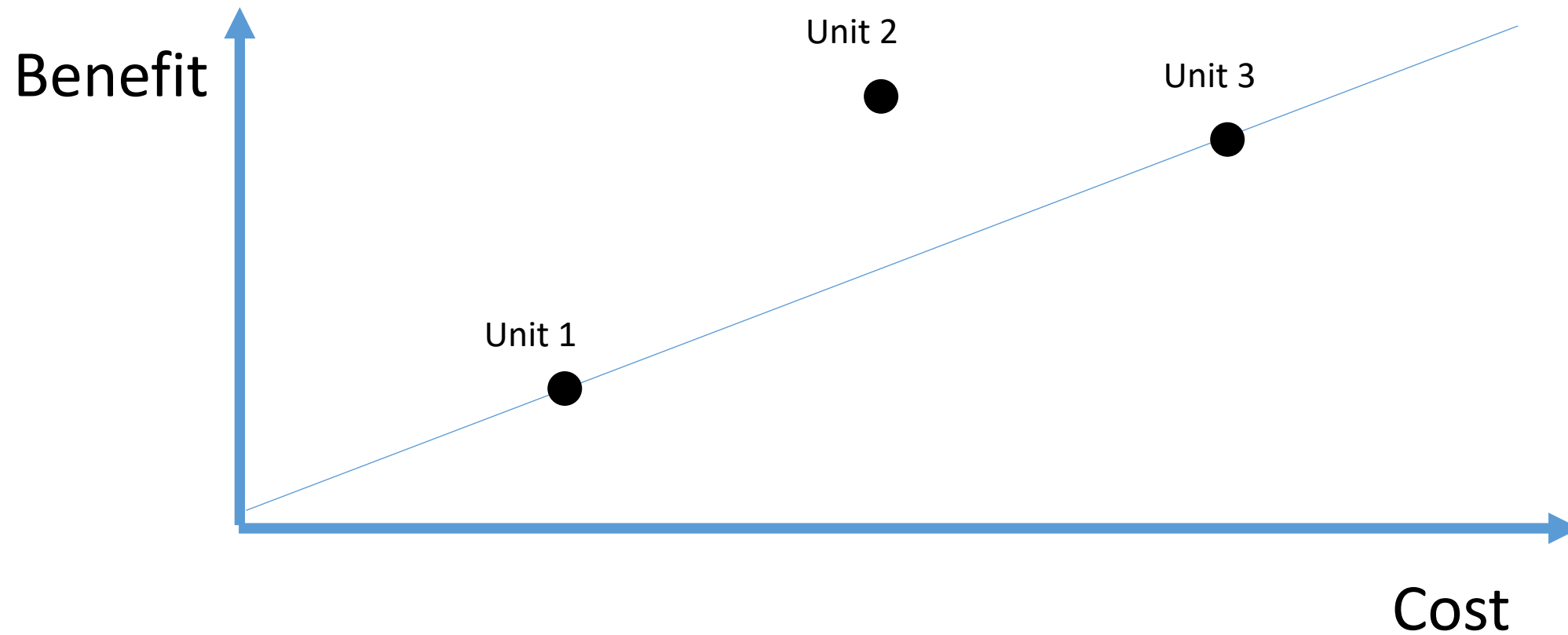
# Why is this not good?



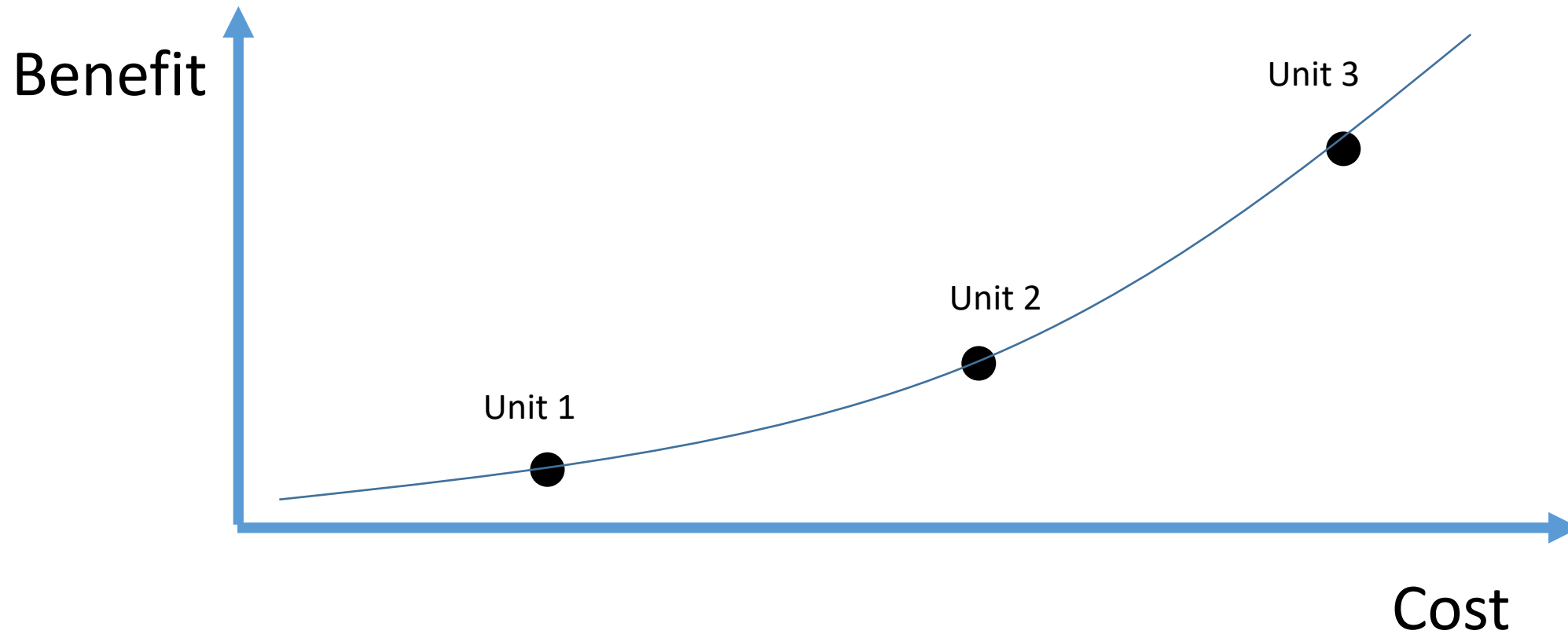
Less interesting decisions and diversity of gameplay



# What exceptions to the rule?

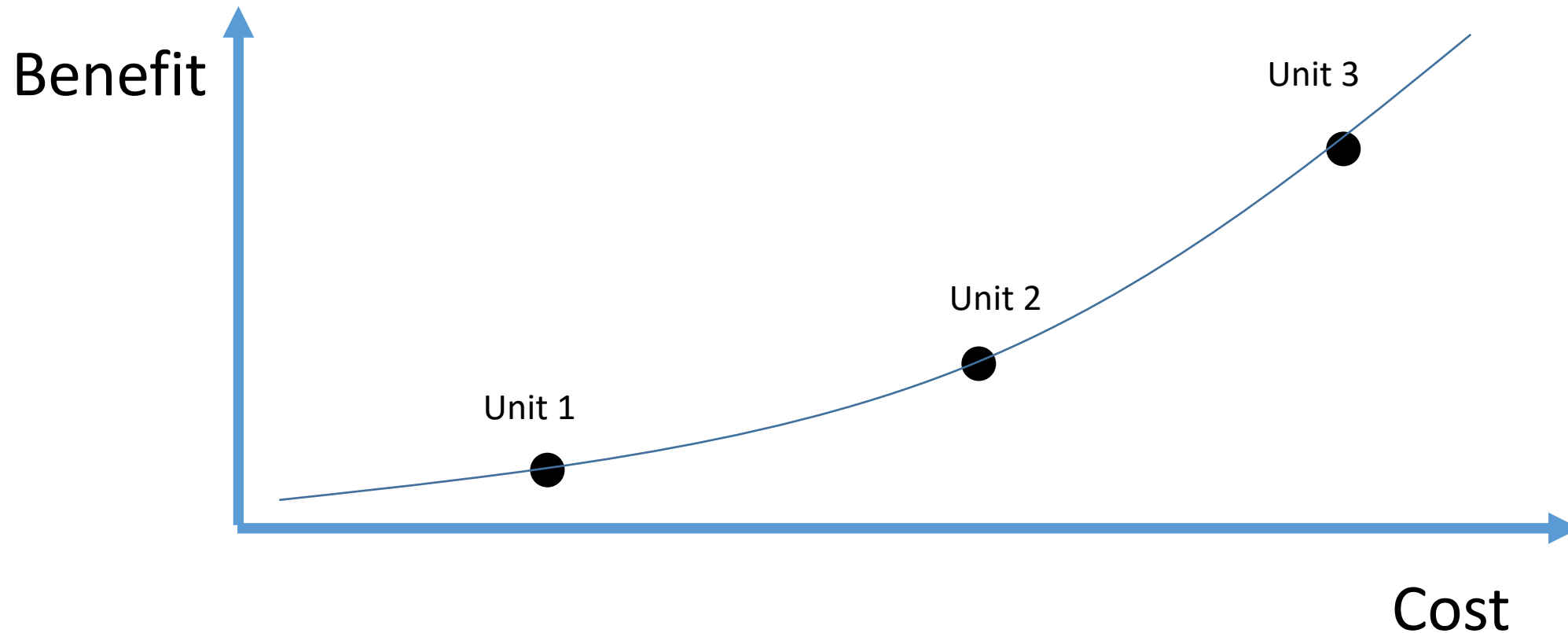


# Why sometimes a nonlinear curve?





# Why sometimes a nonlinear curve?

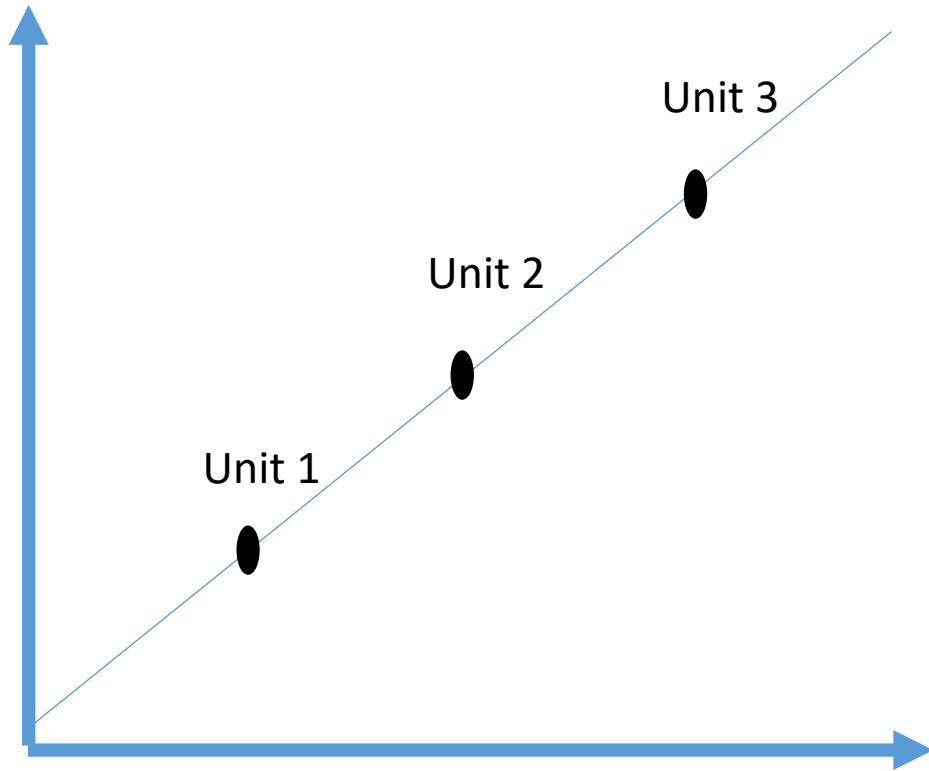


Hearthstone: increasing mana pool => high-cost units only usable late in the game => must have higher benefit



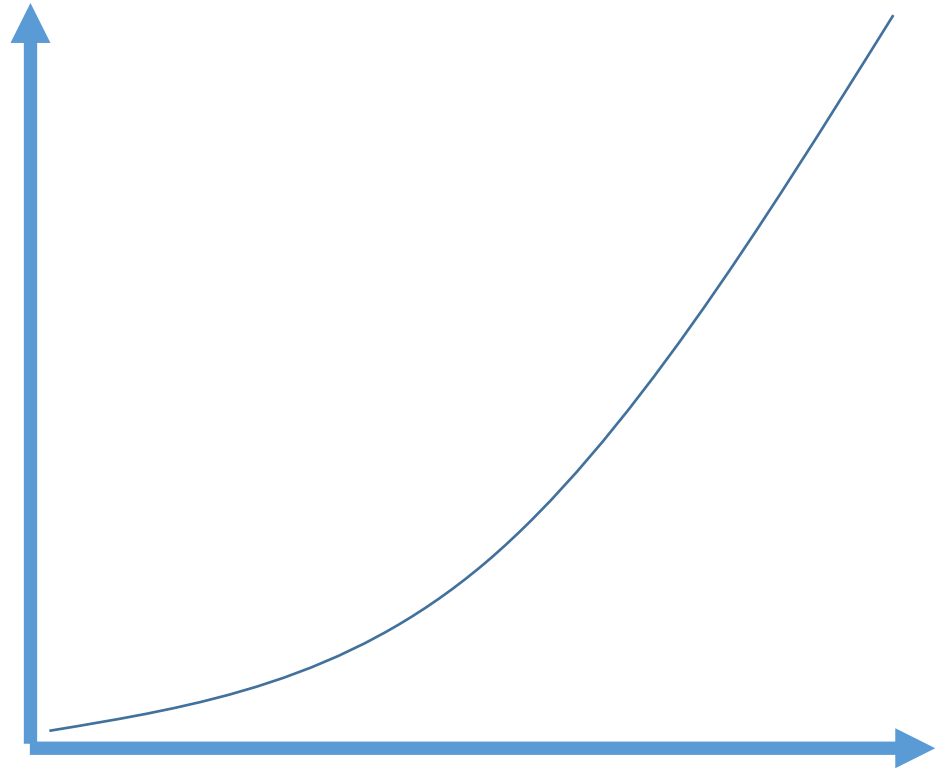
# Remember that these can and do coexist

Benefit



Cost

HP, DPS



Level

# Balancing summary

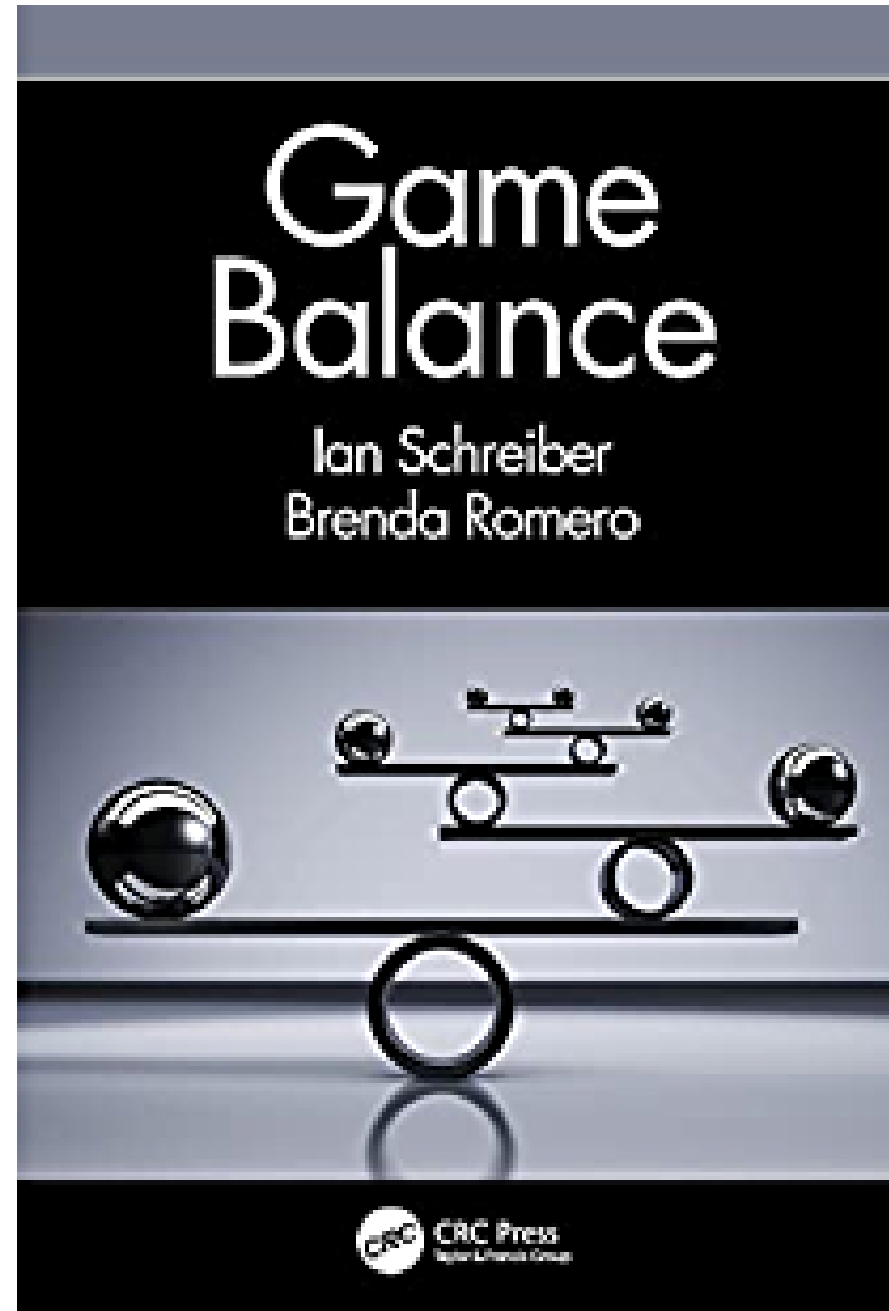
- Math & spreadsheets are a good starting point
- Playtesting still needed, because not everything can be modeled
- Cost-benefit curves (balancing transitive relationships)
- Rock-paper scissors (balancing intransitive relationships)

# Rest of the day: Clash Royale balancing

- Work through the Clash Royale balancing spreadsheet and Colab notebook at your own pace.
- You can also continue on the previous notebook, everyone makes as much progress as they can in this time.
- I will stay here to help, we can go to a breakout room for one-on-one tutoring where you can share your screen.
- Before tomorrow, also try to find time to play Walking Dead No Man's Land (complete 1-2 chapters)



# Resources



# Resources

<http://www.gdcvault.com/play/1024272/Quest-for-the-Healthy-Metagame>

<https://gamedesignconcepts.wordpress.com/2009/08/20/level-16-game-balance/>

<http://gamebalanceconcepts.wordpress.com>

<http://rubycowgames.com/excel-and-google-docs-spreadsheet-tips-for-game-designers/>

<http://rubycowgames.com/excel-and-google-docs-spreadsheet-tips-for-game-designers-2/>

[http://www.gamasutra.com/view/news/36675/Opinion\\_Stop\\_Being\\_The\\_Useless\\_Designer\\_Excel\\_and\\_Formulas\\_.php](http://www.gamasutra.com/view/news/36675/Opinion_Stop_Being_The_Useless_Designer_Excel_and_Formulas_.php)

<http://www.mitchzamara.com/essays/spreadsheet-functions-for-game-designers-part-1/>

<http://www.mitchzamara.com/essays/spreadsheet-functions-for-game-designers-part-2/>

<http://forums.rpgmakerweb.com/index.php?/topic/17393-excel-game-balance-workbook-data-sample/>

<http://iquilezles.org/www/articles/functions/functions.htm>

<https://www.quora.com/How-is-math-used-in-video-game-designing-and-programming>