Bachelor's Degree in Video Game Design and Production

# The Price of Cards:

# Resource Management Systems in Card Games


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This project is dedicated to my friends and family for their unconditional love and support,

to all the lovely people in Morocco who kept me alive,

to my thesis director Mateo Terrasa for his invaluable help,

and to Joan Pons, who could no longer be my thesis director but supported me to the very end.

Thank you.

# Abstract

This thesis investigates resource management systems in card games by analysing various theories and their implementations in some of the most influential card games. The findings are synthesised into practical guidelines for designing and implementing resource systems, which are validated through the development of a card game prototype. The research contributes to the understanding and enhancement of resource management, providing valuable insights and tools for game designers to create cohesive and engaging experiences.

# Resum

Aquesta tesi investiga els sistemes de gestió de recursos en jocs de cartes mitjançant l'anàlisi de diverses teories i les seves implementacions en alguns dels jocs de cartes més influents. Els resultats són sintetitzats en directrius pràctiques per al disseny i implementació de sistemes de recursos, que es validen mitjançant el desenvolupament d'un prototip de joc de cartes. La recerca contribueix a la comprensió i millora de la gestió de recursos, proporcionant idees i eines valuoses per als dissenyadors de jocs per crear experiències cohesionades i atractives.

# Resumen

Esta tesis investiga los sistemas de gestión de recursos en juegos de cartas mediante el análisis de diversas teorías y sus implementaciones en algunos de los juegos de cartas más influyentes. Los hallazgos se sintetizan en pautas prácticas para el diseño e implementación de sistemas de recursos, que se validan a través del desarrollo de un prototipo de juego de cartas. La investigación contribuye a la comprensión y mejora de la gestión de recursos, proporcionando ideas y herramientas valiosas para los diseñadores de juegos para crear experiencias cohesionadas y atractivas.



# Keywords

Resource management, game design, game economies, card games, system design

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# Glossary

Converters: Mechanics that transform one resource into another.

Currency: An agreed-upon tangible medium of exchange for goods or services.

Deck out: Remove all cards from a deck.

Generosity: The balance between sources and sinks.

Land cards: The cards that generate Mana in Magic the Gathering, a resource needed to play nonland cards.

Land drop: Playing a land card in Magic the Gathering. Usually, players want to ensure that they can play lands every turn so they can play the rest of the cards in their deck.

Mana: A resource needed to play cards in most TCGs.

Mana curve: The distribution of Mana costs in the cards of a deck.

Mulligan: Draw again the starting cards to ensure that players can play the game. This action usually includes some kind of penalization to prevent players from drawing indefinitely until they have the perfect hand.

Negative feedback loop: Systems where their outcome leads to a decrease in their future outcomes.

Non-zero-sum games: Games where the total resources lost and gained by all the players do not add up to zero,

Positive feedback loop: Systems where their outcome leads to an increase in their future outcomes.

Resource: A stock or supply of assets that can be drawn on when needed.

Sinks: Mechanics that remove resources from the game’s economy.

Sources: Mechanics that add resources to the game’s economy.

Tap: Turning a card 90º in order to indicate that it has been used.

TCG: Trading Card Game, a type of card game where you can collect and acquire new cards and create custom decks with them, unlike traditional card games where the deck is always the same.

Traders: Mechanics that exchange one resource for another.

Untap: Turning a card 90º back in their regular, vertical position to indicate that it can be used again.

Win Condition: The card or combination of cards that allow a player to win.

Zero-sum games: Games where the total resources lost and gained by all the players add up to zero.

# Introduction

Obtaining, exchanging and maximising resources is often one of the most engaging activities present in games. It's the core of many genres, especially the ones based around specific resources like cards in card games.

These resource systems, often called economic systems, can grow in complexity exponentially, up to the point that certain games attempt to imitate real world economies with all their intricacies. Additionally, each genre utilises economic systems for different purposes, and thus an in-depth analysis requires focusing on a specific genre.

Developing strategies to maximise resources and interacting with all the systems connected to a game’s economy are activities that drive the gameplay and keep players engaged, but when these systems reach their limits and players are left without resources and ways to gain them, or manage to generate so many resources that all the systems related to them lose interest, the game economy breaks and the resulting experience is undesirable. Understanding how these systems work and how to develop failsafes to avoid these extreme scenarios is the purpose of this project.

In this project, the theme revolves around resource management and costs in games, with a specific focus on traditional card games and Trading Card Games (TCGs). Resource management lies at the heart of these games, where players must carefully allocate and utilise their resources to gain an advantage over their opponents. By exploring the intricacies of resource management in card games, this thesis aims to uncover the underlying mechanics and strategies that enable players to make informed decisions regarding resource acquisition, expenditure, and optimization. Understanding how these games handle resources and costs not only enhances our appreciation for their gameplay depth but also provides valuable insights into game design and balance.

The study of resource management in card games is particularly significant due to the nature of these games, as they often feature extensive card pools, diverse strategies, and dynamic metagames, which introduce a myriad of resource-related challenges. Balancing the acquisition and expenditure of resources becomes crucial for players as they navigate the ever-evolving landscape of card interactions, deck construction, and in-game decision-making. And in the realm of traditional card games the focus on resource management remains vital as well. These games typically feature limited resources, such as cards in a player's hand or chips in a poker game, requiring careful consideration of when and how to utilise them effectively. Examining resource management in traditional card games allows us to explore the strategies employed by players to maximise their chances of success, despite the constrained resource availability.

Thus, by delving into the theme of resource management in card games, this project aims to shed light on the various dimensions of these games' economies. From the acquisition and conservation of resources to their expenditure and strategic allocation, a comprehensive understanding of resource management can contribute to the development of balanced and engaging game experiences.

# Research Problems and Objectives

This section aims to explore the key research problems related to resource management systems in card games. This project aims to address these problems in order to contribute to the development of more engaging and balanced resource systems.

## Key Research Problems

Resource Engine Failure: When the resource engines reach limit points (infinite resources or zero resources) they tend to break, resulting in games that are unplayable or devoid of any interest for one or more players. These non-games hamper gameplay and can be frustrating, thus exploring ways to mitigate resource engine failures is crucial for ensuring a smooth and enjoyable game experience.

Modifying Resource Systems: Updating or modifying the resource systems present in a game often require a major redesign of the entire game. This presents a heavy limitation and challenge for game designers as they seek to improve or adjust the game without disrupting the core mechanics or balance of the game.

Deck Building Incentives: Implementing mechanics that incentivize deck building may not appeal to all players, potentially alienating those who only have interest in playing with decks that others have made instead of making their own. To find a balance between encouraging deck building as a metagame strategy and catering to players who prefer pre-constructed decks is an important consideration in resource design.

Oppressive Play Patterns: When a game allows an excessive control of an opponent's resources without providing a way to counteract such actions leads to oppressive play patterns, where players will actively limit the opposing player's agency and create frustrating gameplay experiences. Addressing this problem requires careful balancing of resource-related mechanics to promote fairness and strategic decision-making.

## Secondary Research Problems

Breaking Game Balance: Modifying resource systems can inadvertently disrupt game balance, leading to unintended consequences. Ensuring that changes to resource mechanics do not upset the delicate equilibrium of the game is a crucial aspect of resource management.

Impact on Deck Building: Simplifying resource systems may result in less interesting deck building options, potentially diminishing the strategic depth and variety of gameplay. Maintaining a balance between simplicity and engaging deckbuilding choices is essential for creating a rewarding player experience.

Varying Access to Resources: Providing different strategies with varied access to resources is important for fostering diversity and promoting varied playstyles. Balancing the availability and scarcity of resources to support different strategies is a challenge that requires careful consideration.

Complexity Creep: Introducing additional resources can lead to complexity creep, overwhelming players with an abundance of elements beyond cards, such as dice or tokens. Balancing the need for additional resources with the desire to keep the game accessible and manageable is a key challenge.

Resource Conversion Balance: Allowing the conversion of one resource for another at a low cost can disrupt game balance, potentially creating dominant strategies. Striking the right balance in the game’s converters is crucial for maintaining a fair and dynamic gameplay experience.

Learning Curve: Resource systems can contribute to a steeper learning curve, particularly when they are complex or intricate. Striving for a balance between intuitive resource mechanics and strategic depth is crucial for facilitating a smooth learning curve for new players.

Relevance of Resources: Resources that are used in only a few systems may feel disconnected and irrelevant to the overall gameplay experience. Designing resource systems that integrate seamlessly into multiple aspects of the game ensures that resources remain meaningful and impactful.

## Objectives

The objectives of this project are focused on analysing, categorising, and implementing resource management systems in card games. The aim is to deepen our understanding of the costs and resources involved in these games and provide practical demonstrations of their implementation through a prototype to test the theoretical concepts.

### Analysis of Costs and Resources in Card Games

The first objective is to conduct a comprehensive analysis of the different theories and implementations of resource systems implicated in card games. This involves examining how game designers have approached the task of designing game economies and analysing the implementation of the resource systems present in some of the most influential card games present on the market, with the end goal of gaining insights into how costs and resources shape the gameplay experience.

### Definition of Guidelines for designing Resource Systems

The second objective is to synthesise the findings from the analysis into a set of guidelines for creating card games based on their resource systems. These guidelines will provide game designers with a framework and principles to consider when designing and balancing resource systems in their games. By distilling the best practices and potential pitfalls, these guidelines aim to assist designers in creating engaging, balanced, and strategically rich resource management systems.

### Creation of a Card Game

The final objective is to apply the theoretical aspects of the project by creating a Card Game. This practical implementation will serve as a testbed to validate the guidelines and evaluate their effectiveness in practice. By designing and developing a Card Game that incorporates different resource management mechanics, we can explore the practical implications, challenges, and potential innovations in resource systems first hand.

By accomplishing these objectives, this project seeks to contribute to the understanding and improvement of resource management in card games. The analysis, guidelines, and practical implementation will collectively provide valuable insights and tools for game designers, fostering the development of more engaging, balanced, and innovative resource management systems in card games.

# Theoretical Framework

## Resource management from a Game Theory perspective

Game theory is essentially the mathematical study of competition and cooperation. It illustrates how strategic interactions among players result in overall outcomes with respect to the preferences of those players. **(Jhawar et al., 2018, 63-8)**

In order to classify games from a resource management perspective, **Neumann & Morgenstern (2007)** contemplate how resources are accumulated by players throughout the course of a game, and upon that define two main categories: Zero-sum games where the total resources lost and gained by all the players add up to zero and resources are never generated nor destroyed, and non-zero-sum games, which are the opposite and the total sum of resources does not add up to zero, and may not even be constant. Upon these principles **Jhawar, S., Agarwaal, S., Oberoi, T., Sharma, T., & Thakkar, A. (2018, 63-8)** apply Game Theory to implement policies for resource allocation, as it can be used to model the strategic interactions between two or more rational decision-makers. Since resource management usually involves conflict, Game Theory can interpret and identify the behaviours of the parties aiming for their own objectives instead of the system’s objective. The model of Game Theory applied to the world of management is mainly based on two theories: Two-person zero sum games and non-zero-sum games. In two-person zero sum games the problems are comparable to a duel, where the goals of each opponent are diametrically opposed. An example of this would be in a market regulated by the government where demand is constant, the gain of one company means the loss of another. In this context, Game Theory simulates outcomes based on stakeholders’ interests and self-optimising behaviour. Usually this ends in non-cooperative behaviours even if cooperative competition would result in a win-win scenario. This model allows for planning and design insights that would not be possible using other traditional systems and engineering methods. Additionally, it allows us to simulate different aspects of the conflict, incorporating various characteristics of the problem and generating predictions even in the absence of quantitative payoff information. In order to map resource management problems with Game Theory, **Jhawar et al. (2018, 63-8)** propose three models: Prisoner’s Dilemma, Chicken Game and Stag Hunt.

Prisoner's Dilemma is a theoretical scenario where two suspects are put in prison by police, but without evidence to incriminate them. They are isolated and encouraged to speak to the authorities. They can confess or remain silent. As shown in Figure 1, these decisions lead to the following outcomes:

- If one confesses and the other remains silent, the traitor will be free and the silent will be convicted, staying a long period in jail for non-cooperativeness.
- If both suspects remain silent, they will be released after a short period because of lack of evidence.
- If both suspects confess, they will both be convicted, although for a shorter period than the first case since they cooperated with police.

The dilemma is whether to trust each other and remain silent or confess to try and get out of jail free. **(Jhawar et al., 2018, 63-8)**

**Figure 1**

*Prisoner's Dilemma*

Prisoner 1

| Prisoner 2 | Confess | Silence |
|---|---|---|
| Confess | Both Jail | No Jail<br>Long Jail |
| Silence | Long Jail<br>No Jail | None Jail |

Note. Diagram representing choices and consequences of Prisoner's Dilemma. Own work.

Many natural resource management issues work like a prisoner's dilemma: The dominant strategy is not cooperative, and thus the resulting equilibrium is not Pareto-optimal. **(Jhawar et al., 2018, 63-8)**

The second model, Chicken Game, is a variation of the Prisoner's Dilemma where two drivers are heading to a narrow bridge from opposite directions. The first driver to "chicken out" and swerve will yield the bridge to the other driver and lose. None of them wants to be the chicken, but if no one does both drivers will crash in an accident. In the case of both swerving no one wins, but the crash is avoided. The game has two equilibria in the two outcomes where one driver swerves and the other wins, which are also Pareto-optimal. Thus, the dominant strategy is to do the opposite of what the other player does, as shown in figure 2. Just like in the Prisoner's Dilemma, the best outcome is to win over the opponent and the cooperative solution (both swerving) is not stable since both players want to refrain from it. The difference between these games is that in the Chicken Game if no one swerves both players get the worst outcome, while in Prisoner's Dilemma if both confess the outcome is suboptimal but not the worst possible. **(Jhawar et al., 2018, 63-8)**

**Figure 2**

*Chicken Game*

Driver 1

Driver 2

| | Swerve | Stay |
|---|---|---|
| Swerve | Both humiliated | Win Humiliation |
| Stay | Humiliation Win | Accident |

Note. Diagram representing choices and consequences of Chicken Game. Own work.

The third model, Stag Hunt, is another variation of the Prisoner's Dilemma. In this game both players can either interact and hunt a stag together, or hunt a hare on their own. The stag cannot be hunted individually, and if hunted its value will be shared between the two hunters. The hare can be hunted individually, but its value is lower than half of the stag. In this game the worst possible outcome occurs when one player tries to hunt a stag but the other chooses to discreetly hunt a hare. The hunters might erratically decide to not cooperate, perhaps due to a lack of trust, hence it is also called "Trust Dilemma". Unlike in the Chicken Game, where every player wants to do the opposite of the other, in Stag Hunt both players aim to do the same, as indicated in figure 3. **(Jhawar et al., 2018, 63-8)**

**Figure 3**

*Stag Hunt*

Hunter 1

| Hunter 2 | | Hare | Stag |
|---|---|---|---|
| | Hare | Small Win | Loss<br>Small Win |
| | Stag | Small Win<br>Loss | Big Win |

Note. Diagram representing choices and consequences of Stag Hunt game. Own work.

Game theory is also used to analyse competitive interaction between network providers. The problem is modelled as a non-cooperative game where customers act selfishly according to their objectives. This multi-objective optimization problem can be solved in two ways: Solving one objective first and then using it as a constraint on the next, or concurrently solving all objectives, often using Lagrange multipliers. The Lagrangian method can also be used in cooperative games where coalitions can be formed among various agents. Since the initial case is of non-cooperative nature and auction theory is suitable to solve such games, we can solve the allocation problem using a bidding strategy. **(Zakarya et al., 2022)**

These authors provide insight on how game theory can not only be applied to games, but most real-world problems too, and how resource management conflicts can be successfully mapped and studied using game theory. **Neumann & Morgenstern (2007)**, **Zakarya et al. (2022)** and **Jhawar et al. (2018, 63-8)** use game theory as a framework for studying resource allocation and management outside the context of game design, using it to analyse how different actors, such as firms, governments, or individuals, make decisions about how to allocate and manage resources in a way that is optimal for themselves given the decisions of other actors. **Jhawar et al. (2018, 63-8)** approach is particularly relevant for this thesis, because of the focus on the interaction between agents and how all of the decisions they make affect each other, even if they don't know it or they cannot plan around it. This leads to a myriad of possibilities and opens up broadly the game design space.

## Resources and currencies

In its simplest form, a currency could be defined as an agreed-upon tangible medium of exchange for goods or services. **(Kraj, 2021)**

Kraj elaborates that currencies are bridges between systems, connecting different parts of the player experience. Resources, on the other hand, are useful by themselves. Most players will consider coins or gold examples of currency in video games, and while this is usually a very valid answer, it is not always the case. For example: Mario's coins or Sonic's rings are not a currency, they are resources with a tangible use within the game's mechanics. Currencies can be exchanged for resources, which have proper value and usage within the game. **(Kraj, 2021)**

**Serpa (2020b)** adds that almost anything can be a resource in a game, from concepts that influence the game-state to elements controlled by the player are all understood as resources. Fixed elements such as barriers and floors are usually not considered as such. Not all game mechanics need to be related to the internal economy of a game, even if all resources are. The mechanics that do not interact with resources by means of production, consumption or exchange are not directly related to the economy.

When categorising types of resources, **Adams & Dormans (2012)** distinguish between tangible, intangible, concrete and abstract resources. Concrete resources are resources that exist within the game world and can be subdivided into tangible and intangible, where tangible resources have physical properties in the game, for example a piece of wood that can be grabbed and thrown around. Intangible resources on the other hand do not exist physically in the game and do not occupy space, for example a representation of pieces of wood in your inventory that simply lists their amount. Abstract resources do not exist within the game world but have an impact in the game. For example, having a certain position might grant strategic advantage. This is an abstract resource not quantified by the game's mechanics, but it affects the game state nevertheless. Abstract resources are opposite to concrete resources since concrete resources are visible and recognized by the game and players alike.

**Kraj (2021)** states that we base our perception of currencies in our society: almost anything can be acquired with enough money, but this doesn't have to be true for games: Some resources can be disconnected from the game's currencies, making them impossible to be bought or sold, and thus rendering their whole system isolated. Resources can also be a currency at the same time, if they have a tangible use and can also be traded. The distinction between resources and currencies is often a grey area, and thus they are often treated as the same thing in game design. This facilitates discussing them, but knowing their differences will allow designers to create interesting and robust systems. The first question that needs to be answered before deciding the number of currencies in a game is “What will these currencies be used for?”. Some answers could be buying swords with gold for your character, or trading bones for power with your local witch. While these answers are valid, they are too narrow and micro: They don’t justify the existence of a currency, they just list where it can be used.

Instead, what needs to be answered is “Which pillars of my game would be strengthened by an economy? Are these aspects connected to each other?”.

We can imagine some outlier scenarios to better illustrate the problem of the number of currencies in a game. Consider a game with a single currency: all systems are linked to it. The moment the players discover which system gives them the most coins, all the other systems become obsolete and uninteresting, and can be bypassed instantly with all the coins amassed.

On the other hand, a game with a currency for each micro-system, presents very different problems: Even if every system is isolated and can be balanced individually, the player agency is dramatically low, forcing them to interact with every system in the game to progress. Also, the game will feel daunting to play, with hundreds of currencies to manage and mentally model. Another issue is that it will make the game feel artificial and “gamey”. **(Kraj, 2021)**

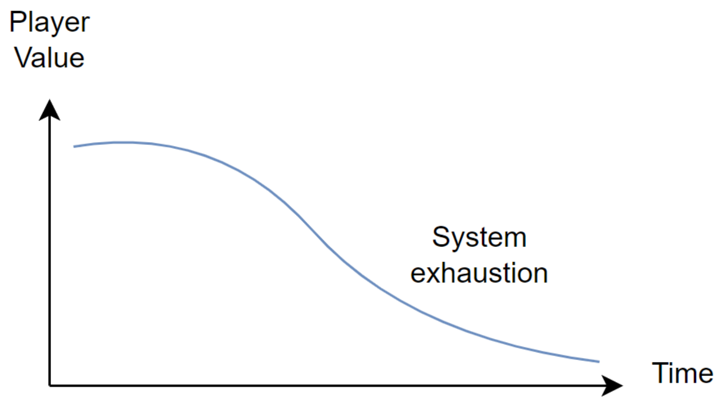
Some useful considerations in order to implement economies in a game are:

- Use currencies as the smallest reward
- Pay attention to currency exchange
- Consider different playstyles when implementing currencies

As shown in figure 4, the value of a currency will fluctuate over time, and it’s part of player progression. Usually, its value will decrease over time since at the beginning the player has everything to purchase but, eventually, the player will get richer and will have fewer things to acquire, up to a point where the currency is useless and all their related systems die with it. **(Kraj, 2021)**

**Figure 4**

*Value decrement over time*

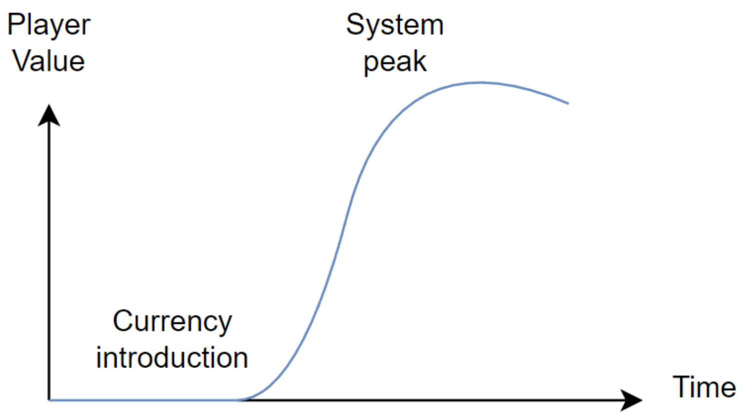



Note. When a player exploits a resource, they inevitably decrease its value. Own work.

The opposite can also be true and some currencies can increase value over time, as indicated in figure 5. This can happen when a currency is linked to late-game systems that are unavailable or unfeasible for new players but can be completed eventually. At this point, this currency will become one of the most if not the most valuable in the game, becoming one of the main drivers in the player experience. **(Kraj, 2021)**

**Figure 5**

*Value increment over time*

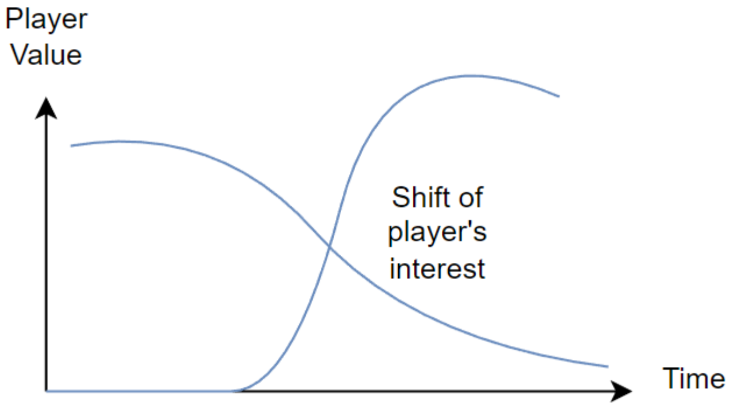



Note. Not all systems are meant to be exploited early on, and this can generate interest in late stages of a game. Own work.

These two situations can and should be happening simultaneously, as shown in figure 6. This enriches the player experience by providing a variety of goals at each stage of the game, all of them with proper rewards, along the duration of the game. With proper planning, this makes a dying currency a good thing for your game. **(Kraj, 2021)**

**Figure 6**

*Combined value over time*




Note. When the two systems are combined, player interest is always kept high and variety is increased. Own work.

Both supply and demand are directly linked to the value of a currency. In real economies these metrics are extremely controlled, but **Kraj (2021)** argues that translating them to games inherently simplifies them, rendering them unsustainable in the long run, as it happened in the game Diablo 2, where the whole game was based on a single currency, gold. Unlike in real life, gold in Diablo was constantly being generated by players out of thin air. While this was somewhat fine for the single player mode, the balance was utterly broken in the multiplayer mode. Players quickly became so rich that keeping gold in their inventory was not worth the loss of space. Since gold became worthless, players started trading and creating commodity currencies, and gold was supplanted by the Stone of Jordan, one of the rarest rings in the game. On the game-driven aspect of the economy, the prices stayed the same, so they virtually became free because of the extreme deflation, and massive parts of the progression and core loop became irrelevant as a result. Eventually, even the Stone of Jordan became worthless and was supplanted by other items turned into currency. Another example of a game economy stretched to its breaking point provided by **Brown (2022)** is in the game The Witcher 3, where players discovered that they could kill the cows in White Orchard, sell their leather, and meditate to let the time pass, so all the cows could quickly appear again. This simple process could be repeated endlessly to amass infinite wealth before leaving the very first village in the game.

To sum up, the relationship between resources and currencies in video games is a complex one that designers must fully understand in order to create a compelling and well-rounded experience for players. As **Adams & Dormans (2012)**, **Kraj (2021)**, **Serpa (2020a, 2020b)** and **Brown (2022)** stated, resources are the fundamental building blocks of gameplay, whereas currencies are the connectors that tie these blocks together, creating an interlinked economy. It is also important to consider the purpose of different currencies in a game and how they could strengthen the overall experience. **Kraj (2021)** also highlighted the fact that currency values are dynamic and are subject to change based on player actions. Overall, this understanding of resources and currencies can help game designers to create more engaging and dynamic economies in their games.

## Sources and Drains

In order to structure a game economy, **Adams (2014)** defines four core elements: Sources, Drains, Converters and Traders.

**Sources** are mechanics that add resources to the game's economy through a production rate. They can be activated through certain conditions or timed, but never require resources to do so. Sources are not the only way to obtain resources.

**Drains**, as opposed to Sources, are mechanics that remove resources from the game's economy through a destruction rate. They can also be activated through conditions or periodically. They are used to balance resource production and not always have a negative effect: sometimes it is beneficial for the player to get rid of certain resources.

**Converters** are mechanics that transform one resource or currency into another permanently through a conversion rate. In practice, they work like a Source and a Drain simultaneously, creating a new resource and destroying the old one in the process. Converters can be tweaked through conversion rates and limiting the resources accepted and provided.

Finally, **Traders** are mechanics that exchange one resource for another through a trading rate. Unlike Converters, Traders do not destroy resources, all resources traded still exist in the game once exchanged, but they belong to different entities.

All rates of production, destruction and conversion can be tweaked depending on the game's state to improve gameplay. This is usually done through upgrades or downgrades. An economic system is not only composed of its currencies and resources, but also by the dynamics between them. How resources are created, for what they are exchanged or how and when they are destroyed are all crucial elements of a game's economy.

Upon these core elements, **Serpa (2020b)** states that from the point of view of the player, a Trader is just another Converter that exchanges one resource for another. In terms of game economy though, this is not the case. Converters can maintain a player's resource equilibrium, keeping the approximated number of resources a player holds the same, and Traders can keep a global resource equilibrium, keeping the number of resources in the whole game the same.

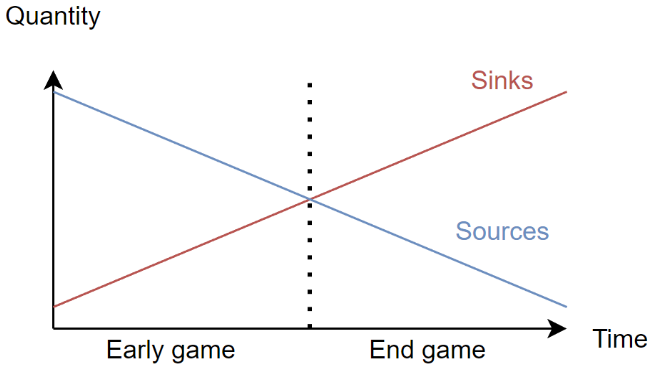
This does not necessarily mean a balanced game state, nor is a requirement to obtain one. Another author, **Brown (2022)**, includes another core element to a game's economy: the **inventory**. It serves as a middle step between sources and all the other key elements, conditioning how players interact with them and how they manage resources in the process. A limited inventory might compensate infinite sources by restricting how much can be gathered from them at any given point, preventing players from stockpiling infinite amounts of resources that would otherwise make the game trivial, and incentivising the use of scarce resources by limiting how many of them can be accumulated, thus giving further tools for designers to enhance both how flexible and how generous sources can be. **Serpa (2020c)** adds that sources and sinks are mostly used to control how resources are added and removed from the game, but converters and traders serve another key purpose: control how resources are balanced and distributed throughout the game. In the case of converters, they can be used to achieve a global resource equilibrium, controlling the number of existing resources of each kind. On the other hand, traders can be used to achieve a local resource equilibrium, maintaining the total amount of resources constant but transferring ownership from different entities.

These key elements –while extremely useful– are not mandatory to maintain a game's economy, and plenty of games are functional without one or more of them. For example, early titles of the Final Fantasy saga do not contain Traders. Each currency in a game will need sources and sinks, the number of which is determined by its systems and expected player experience, adds **Kraj (2021)**. How each system contributes to the game's economy is key to achieving balance in a game: Pace, progression, game feel, difficulty, flow… All those aspects and more are directly related to the implementation of the game economy, and what the designers decide to be sources, drains, converters and traders. And, ultimately, to make a good game, every decision matters. **(Serpa, 2020b)**

In the context of game economies, generosity refers to the balance between sources and sinks. A game where everything is prohibitively expensive is not interesting, and forces players to grind endlessly to obtain even the most basic rewards. The opposite is problematic too: Even if initially rewarding, the players will very rapidly get bored with broken systems, rewards that feel dull, and complete systems rendered useless. What **Kraj (2021)** advises is to experiment with both sides of the generosity spectrum along the game. At the beginning, players are eager to unlock as many things as possible, thus having generous sources will allow them to quickly engage with the game's systems in a satisfactory manner. As the game progresses, the players will want to specialise and unlock more powerful rewards. While this is happening, sinks should grow along their needs, making their desires stronger and improving their retention, as shown in figure 7.

**Figure 7**

*Inverse currency balance*

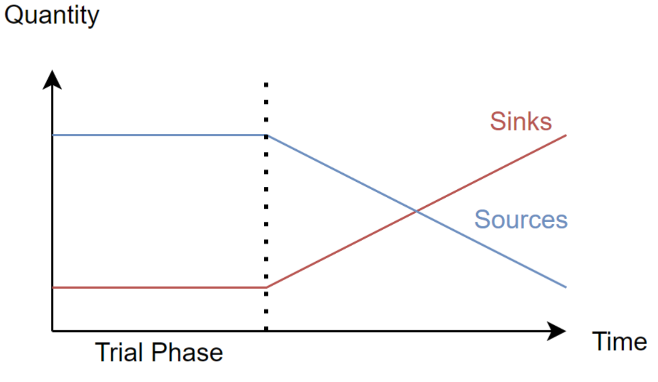



Note. As the sinks increase, the sources get depleted. Own work.

Each game is different and the ideal balance will never be exactly the same. For example, in a free-to-play game with a hard currency (real money) doubling a soft currency (in-game coins), the curve may be very different, as shown in figure 8. The curve is designed to have an initial "hooking" period, where the purchase of hard currency is not necessary, and eventually the balance changes when the "trial" is over. **(Kraj, 2021)**

**Figure 8**

*Free-to-play currency balance*




Note. Once the trial phase ends, generosity plummets. Own work.

**Kraj (2021)** states that a useful tool to help balancing sources and sinks is using a global metric: currency per time frame. By knowing exactly how much currency a player will generate in an hour, the sinks can be calibrated with ease. For example, in a 2h play-sessions, on average players will earn 5000 gold. The fishing minigame can be balanced around it by tweaking it to generate 4000 +-1000 gold per hour. Additionally, players can be incentivized to engage with certain systems by giving them a higher return than the global average.

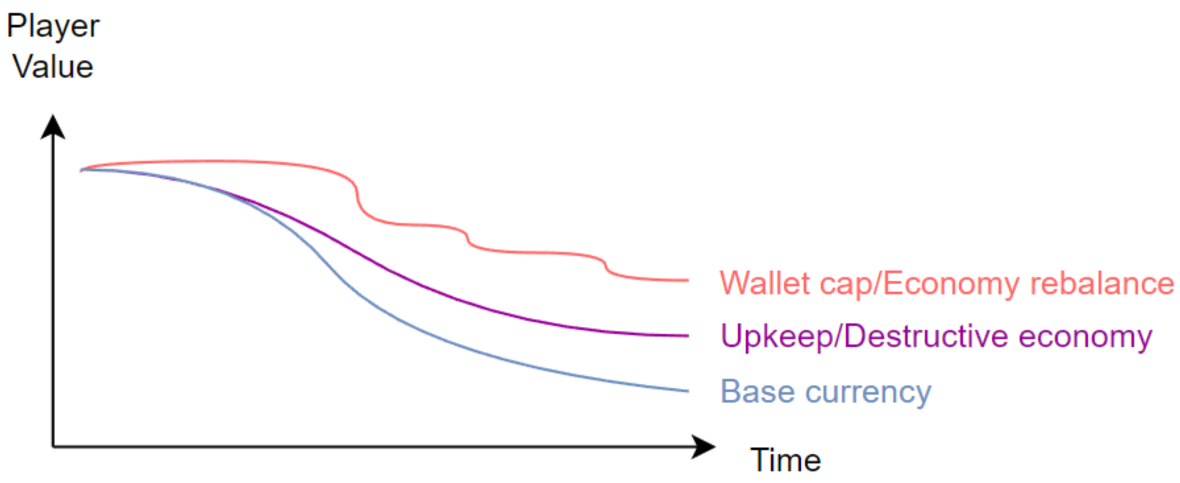
Is it possible to create a strong, sustainable virtual economy? My answer to this question is pretty brutal: no. Whatever you do, your economy will crash, and your currencies will become worthless. The faster you accept it, the faster you will put failsafes in place to try and contain this drop. **(Kraj, 2021)**

Compared to real-life economies, games have too many flaws: There is no limit to virtual currencies, they can be hoarded endlessly and game design generosity is naturally tweaked to disbalance the system. Additionally, catering to every player will disbalance the economy even more. There are too many inherent problems for them to work in the long run. Having defined why game economies are doomed to fail, **Kraj (2021)** presents a series of strategies indicated in figure 9. These failsafes have helped him in order to develop his games and mitigate the flaws in their economies:

- Removing or heavily taxing player transactions. Can feel oppressive but it’s highly effective.
- Creating multiple, specialised currencies to keep systems isolated.
- Implementing destructive transactions to remove currency from the game.
- Establishing upkeep prices to tax players the richer they get. This one is very unpopular but can work very well.
- Limiting inventories/wallets to prevent massive hoarding.
- Rebalancing the economy altogether if it’s broken beyond repair.

**Figure 9**

*Economic Failsafes*

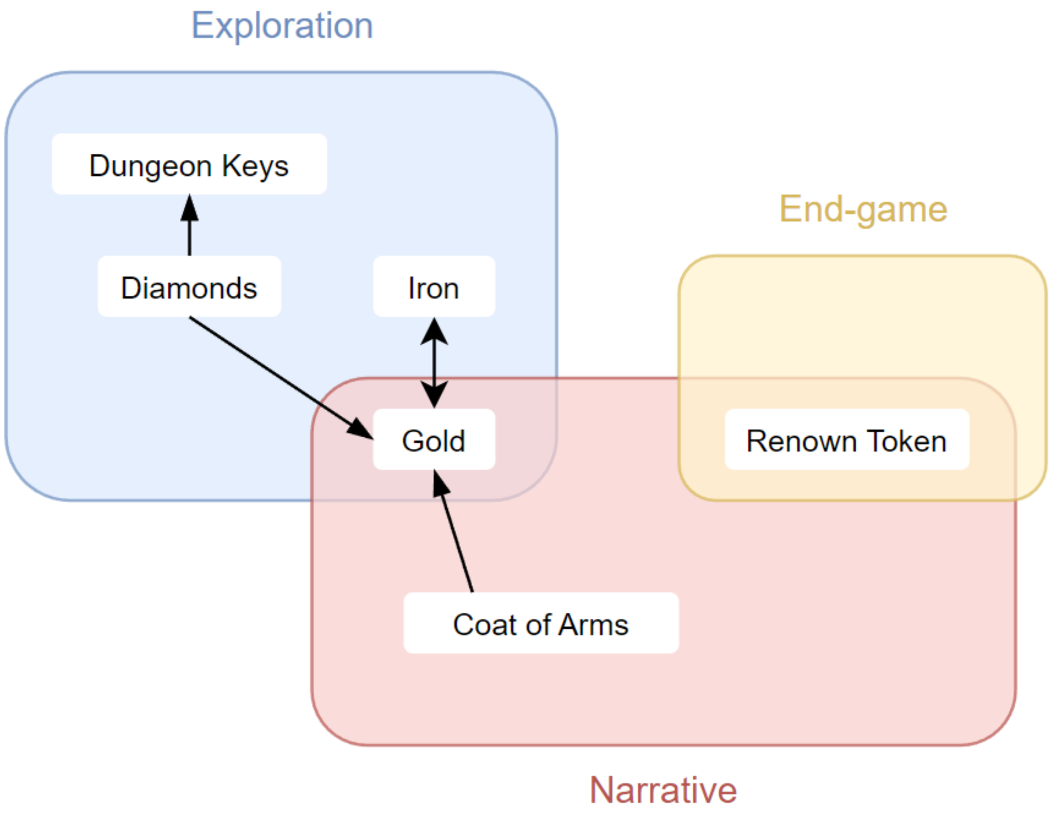



Note. These failsafes mitigate the issues of a game economy, but they are not a long-term solution. Own work.

These strategies don't solve the issue altogether, but they do buy you time, adds **Kraj (2021)**. Perhaps enough time to release a new expansion, introduce a new currency, rebalance old systems, etc. Real life economies are defined by finite amounts of currency. And while this may seem an obvious solution, it has been tried in old school MMORPGs like Ultima Online and always ended up the same: Players hoarded currency and, because they were not forced to spend money, the economy froze and was a complete failure. During the design phase of game development, **Kraj (2021)** recommends using high-level documents to properly establish the game's economy. These documents consist of a definition of the economic pillars of the game, a list of all the currencies linked to their respective pillar and diagrams of the flows of currencies and possible exchanges between them, as indicated in figure 10.

**Figure 10**

*Economic Pillars and their currencies*




Note. Defining these pillars and their connections helps to create systems and bridges between them. Own work.

With the previous figure, we can deduce:

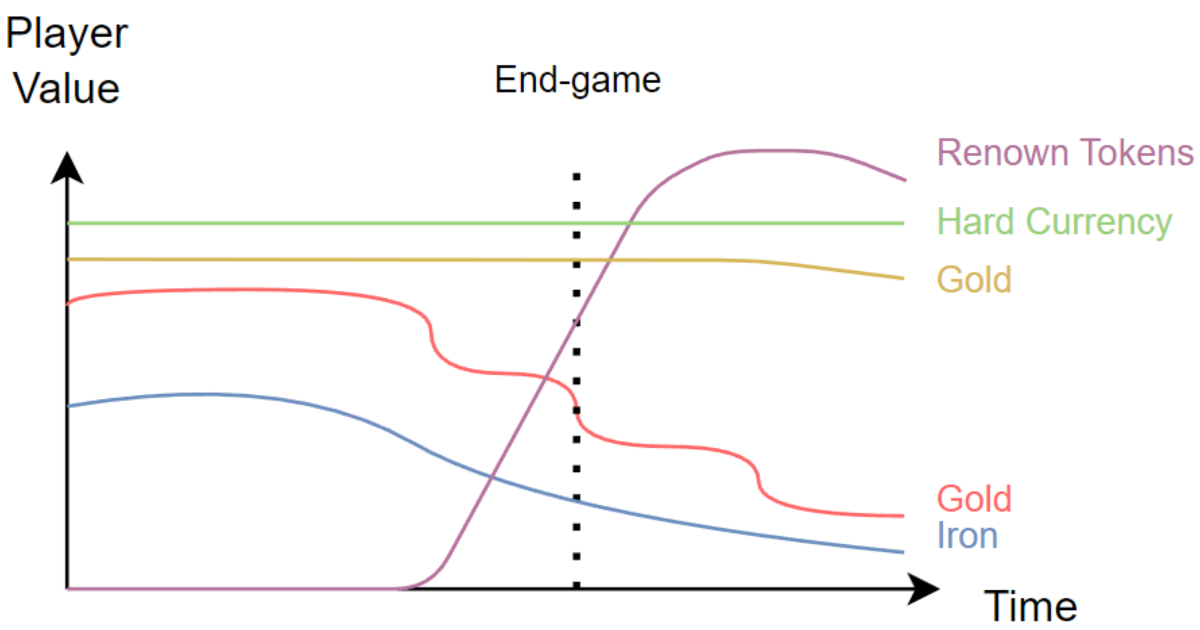
- Iron is an early-game resource destined to eventually lose its value and that's fine, it will serve its purpose at the beginning of the game and eventually become less relevant.
- Gold is a key resource that needs to maintain value until the end-game where it will be replaced with renown tokens. This could be achieved with scaling prices from new vendors (economy rebalance).
- Diamonds are a protected resource and thus need to be seen as a valuable resource from beginning to end, and have useful applications both early-game and end-game. It's practically inevitable that their value drops off a bit late-game.

- Renown Tokens are designed to be an end-game currency and thus will not be interesting for players early on, but will eventually scale in value and be a main driver for end-game players, probably even surpassing Diamonds and the Hard Currency even if only for bragging rights for experienced players.

The economy of this game is designed to engage players throughout the game, providing different systems and motivations in order to create a fulfilling experience. Two phases can be clearly defined: Early/mid-game and end-game, as shown in figure 11. **(Kraj, 2021)**

**Figure 11**

*Complete economic progression*




Note. The different progressions of currencies in a game should complement each other. Own work.

As a summary of the techniques and strategies that have worked for him in the past, **Kraj (2021)** establishes 12 keys for economic systems that consist of the following:

- Identifying what will be a currency in the game.
- Defining the number of sources and sinks of a currency based on player agency.
- Both excessive and too little generosity will lead to a decrease in player count.

- The balance of sources and sinks for a currency can change over time and can be used to drive player behaviour, catering to their current motivations and needs.
- Balancing systems by defining a global amount of currency per unit of time, and then tweaking the numbers of specific systems.
- The economic pillars of a game are key to establishing the game’s economic system.
- The game’s systems define the number of currencies, their relationships, the level of player agency and the safety nets needed to sustain said systems.
- It’s useful to define the semantics of a currency to understand their field of action.
- Strategize around the perceived value of currencies over time, and predict how they will compete at different stages of the game.
- Game economies are destined to crash. Accept it and plan accordingly.
- Establish powerful failsafes to delay the deprecation of your currencies.
- No system will be perfect on the first try. Iteration and testing are crucial to create and polish strong economic systems.

In the context of understanding and implementing the key elements of a game economy, we can see that every author has their own interpretation of how Sources, Drains and other key elements should work.

The nuance added by **Adams (2014)** and **Brown (2022)** when defining the core elements of a game’s economy allows for a deep control of the game by the designers, and thus more tailored, balanced and interesting experiences in game, as **Kraj (2021)** and **Serpa (2020b, 2020c)** proved with their in-depth analysis and implementations.

## Design patterns in Game Economies

**Brown (2022)** elaborates that designing and implementing game economies can be a daunting task, with ample room for abuse and imbalance. But, if the balance is right, it can serve as a very powerful tool capable of shaping player behaviour, defining the pace of progression and providing challenging choices for the players. And as **Floyd & Portnow (2016)** pointed out, games usually suffer from a big problem from a real-world economic sense: everybody is constantly printing money, which does not come from a limited reserve or represents a defined supply, it is generated out of thin air. This does not only apply to currencies but to all kinds of resources too, and they are all constantly being added to the game's economy. As **Adams & Dormans (2012)** state, the term "game economy" uses a broad definition of economy, not only referring to money, but to any and all systems in which resources and currencies are generated, exchanged and consumed.

Incorporating virtual economies into games is an idea already present in the nineties, states **Kraj (2021)**, when Zachary Booth was implementing an economic system into Ultima Online. He stated that the benefits of an economic system were to ration power, support specialisation (not possible to buy everything), encourage player interaction, provide goals and support role-play. Most games have a very simple economy (if any), just enough to support the experience and add interest to their different systems. There are some constant aspects between systems though, like their core: currencies and resources. Games are defined by their economic systems. Pacing, player objectives and behaviour, tough choices and social interactions are all subject to them. Thus, economic systems are a very powerful but dangerous tool since they are the framework overarching all exchanges and trades. In multiplayer games, the economic system usually tries to imitate a real-life one with supply and demand from the player base and a regulating entity from the development team. In some cases, the economic system is so advanced and so central to the game it becomes the main selling point, like Eve Online which employed Ph.D. economists to maintain the game and publish periodic economic reports about production and inflation within the game.

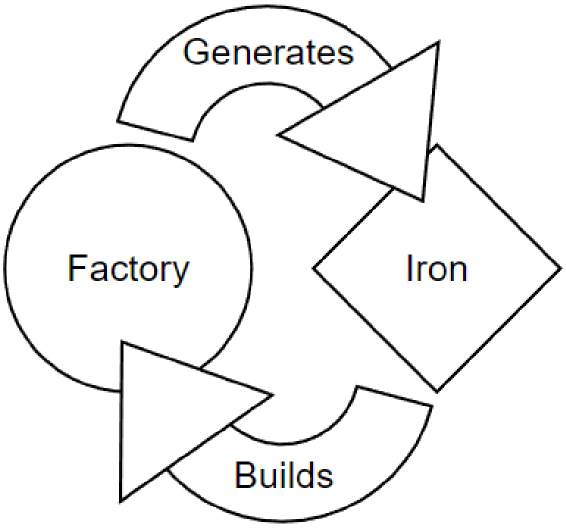
Most games have an internal economy where resources are produced, consumed and exchanged, adds **Serpa (2020b)**. This system's importance and complexity varies from game to game, especially when comparing between genres. All the game's resources and mechanics manipulated by the players are encompassed by the game economy, and any concept that can be measured numerically is a resource. **Loon et al., (2015)** argue that unlike simulations, which are models characterised by being homomorphisms of the aspect of reality which they aim to replicate, games involve cooperating or competing against the set of rules and constraints defined within the game setting, and while games have become increasingly more complex, they are inherently conceived with different goals than real life economic systems. This this inevitably leads to a loss of nuance in the process of designing and implementing resource systems in games –often called economic systems– and opens the door to a myriad of scenarios that simply could not be conceived when analysing real world economies, such as the possibility of creating infinite resources or having a single entity (the developers) which controls and regulates the entire economy as they see fit.

In an example game created by **Serpa (2020b)**, where you give flowers to villagers to gain their friendship, he states that friends are the most valuable resource, since collecting a certain amount of them wins the game. The rest of the resources are more or less equally valuable, depending on the game state. If a certain villager wants a specific flower, and gifting it would grant you his friendship, the value of that flower increases dramatically. Since players don't have access to the exact number of flowers needed to gain a friendship and the number of flowers and trades allowed changes daily, the actual value of flowers fluctuates and is imprecise, forcing players to take risks. If a high-value flower or a low-value flower is destroyed, all others' values are affected by it, and all values are directly related to the production of flowers. Another example game created by **Vaughn (2021)** links sources of one resource to the sinks of another to create interesting decisions. The game is centred around managing a school and two of the main resources, Funds and Happiness, are connected: Increasing Happiness usually requires spending Funds, and in order to gain Funds, new policies and conditions have to be accepted that will decrease Happiness. This creates a dilemma for the player that will condition their strategy and drive gameplay to keep the game interesting.

When implementing game economies, one of the most common patterns are Feedback Loops, says **Adams (2014)**, which occur when a production mechanism requires some of the resources generated to work, as shown in figure 12. This system can sustain itself as long as the generated resources outweigh the drained ones, but if the resources needed get depleted, the system will cease to function, creating a Deadlock. As **Serpa (2020c)** elaborates, not all production mechanisms form feedback loops, and some may form loops that span through multiple mechanisms until the result is fed back to the initial one.

**Figure 12**

*Resource Feedback Loop*




Note. The interactions of resources are cyclical, creating a Feedback Loop. Own work.

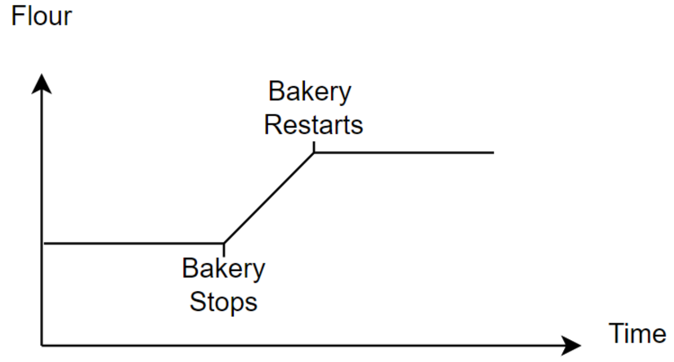
A feedback loop also occurs when multiple production mechanisms require each other's output to work, and if the resources were to be destroyed or spent elsewhere, all systems would halt, generating a Deadlock. In order to avoid Deadlocks, either all loops in the economy need to be removed, or an alternative Source needs to be created for one of the resources. This is why Monopoly rewards its players money when they pass "Go": A player without properties does not generate money, and without money no property can be bought, creating a Deadlock. The solution is to give players a 200$ each time they pass "Go", a sum small enough to not break the balance of the game, but prevents them from being locked out of the game. **(Adams, 2014)**

Another common pattern that **Adams (2014)** identifies when implementing game economies are equilibriums. Static equilibriums occur when the number of resources generated and drained in a system remain the same over time. When the resources fluctuate through a cycle that eventually returns to the starting point, the system is in a Dynamic equilibrium. Suppose we have a system where flour is created in a mill and then converted into bread in a bakery. If the flour consumption rate equals the production rate, the total flour in the system remains constant. If one of the two elements were to be paused temporarily, the total flour will change until the paused system starts again, and then the total flour would once again be constant. As figure 13 shows, the system returns to a Static equilibrium because the production and consumption rates remain equal.

If the bakery and the mill cannot operate simultaneously, the flour will add up until bread can be made, then be depleted to make said bread. The system now is in a Dynamic equilibrium, where resources are constantly fluctuating but eventually return to the original conditions, as shown in figure 14.

**Figure 13**

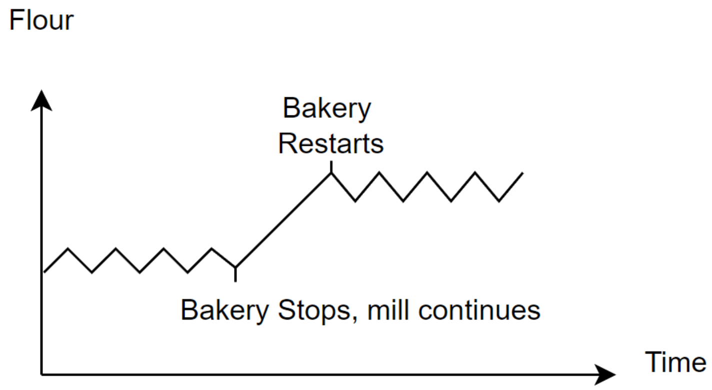
*Static Equilibrium*




Note. The sum of total resources remains constant in a Static equilibrium. Own work.

**Figure 14**

*Dynamic equilibrium*




Note. The resources oscillate in periodic cycles in a Dynamic equilibrium. Own work.

A game that operates in a Static equilibrium can be easily analysed by its players: since everything remains constant, different elements of the economy can be tested in isolation if only one thing is changed. This results in an easy to learn and play game. Dynamic equilibriums on the other hand, are harder to understand and manage, since everything is constantly changing, players have a hard time understanding if what they are experiencing are the consequences of their changes or just fluctuations that naturally occur in the game economy. When a game falls into a state of equilibrium, Dynamic or Static, the player is relieved of pressure, for they can leave the game just play itself and remain in balance. In order to prevent predictable play patterns and create more interesting experiences, most games add an element of chaos that, if uncontested, ends up shutting down the economy. This ensures that players remain engaged and keep looking for ways to sustain their production. In order to prevent creating stale systems that just grow by themselves, player action should always be necessary to ensure growth. Players should be the ones pressing the metaphorical gas pedal of the game, for that's their main challenge: figuring out what to do in order to progress. The player is the main element of a game's economy and progression should require their active participation. **(Adams, 2014)**

Overall, these authors offer different perspectives on the topic of game economies, with **Kraj (2021)** providing a theoretical framework for understanding the role of resource management in games, **Serpa (2020b, 2020c)** and **Vaughn (2021)** demonstrating the practical application of game economies through their own games, **Brown (2022)** and **Floyd & Portnow (2016)** providing increased nuance to already established theories, **Loon et al., (2015)** and **Adams (2014)** providing additional context and nuance in the differences between real world and game economies, and **Adams & Dormans (2012)** identifying common patterns in the economies of many different games. Together, their work can provide a comprehensive understanding of the role and importance of game economies in creating a satisfying and engaging player experience, and how nuanced it is the implementation of such systems.

## Resource-based Objectives

At the beginning of a game, the player has an abundance of options but a shortage of resources but, as the game progresses, the resource generation increases and the number of options where to spend said resources decreases, and thus all the game's dynamics related to resources will evolve over time. This is what **Serpa (2020b)** defines as the resource-based progression of a game, and in order to create it they define the following guidelines:

- Defining a main inspiration to base the system around.
- Defining the progression resource that needs to be collected to win.
- Defining the main source of the progression resource.
- Defining the main mechanic based on how the source of the main progression works.
- Establishing additional mechanics to add variation.
- Prototyping and testing the systems defined.
- Iterating and evolving the design until it fits the game and feels good to play.

**Serpa (2020b)** adds that, while starting with a good mechanic idea can work, it’s not something reliable, and thus having an established system will be more consistent and will also help to define the scope and structure of the project.

Having an established conception of “what will the players do” is extremely useful in order to define the game pillars and, once defined, economic pillars can be mapped around them with ease. **Kraj (2021)** puts as an example an exploration-based game, where there could be multiple resources that can be obtained in the different locations of the game, incentivizing players to move around the map and explore. Or in a Social/Collaborative game there could be multiple currencies that require player specialisation to be obtained, and thus incentivizing players to distribute tasks and trade between them in order to have access to all currencies.

Upon these principles, **Serpa (2020a)** argues that game progression can be understood from an economic point of view by interpreting progression as the process of gathering a resource. The element that needs to be acquired (or lost) to finish the game represents the distance from the beginning of the game (no resource or 0% of it) to the end of the game (resource obtained, or 100% of it). This resource that measures in-game progression can be understood as the progression resource. With the progression resource defined, all game mechanics and systems should be designed around it. This also serves the purpose of being a creative constraint that can help approach the in-game possibilities from multiple perspectives.

Resource progressions can be understood in multiple ways:

- The path as a resource, where the game's journey can be interpreted as a gathering, and player's advancing through the game mean the "path" is being collected.
- A literal collection, where the game objective is to collect a resource, or in some cases, get rid of a certain resource. In space invaders the enemies are the progression resource and, once they are all destroyed, the player wins.
- No end goal, even if there are objectives present within the game, is another common implementation. This is especially present in open-ended and sandbox games, where players just toy around with game mechanics instead of pursuing a clear, defined objective.

This approach breaks the initial assumption that progression resources can be used to plan the game elements and mechanics. If there is no primary goal to be achieved, what will guide the game design? This will mean that the progression resource approach might not be helpful. **(Serpa, 2020a)**

These authors contribute different perspectives on game theory concepts, game design guidelines, and the use of different resources to drive game progression. The theories of **Serpa (2020a, 2020b)** provide a comprehensive understanding of the management and allocation of resources within a game and how to design a well-structured resource management system, as well as introducing the key concept of the progression resource. The contribution of **Kraj (2021)** is also important as it provides an understanding of how different resources can be used to drive game progression and player motivation, thus allowing the design of a game with a well-structured resource management system.

## Resource Management in Card Games

In the game Magic: The Gathering, Mana is needed to play cards. **Cunningham (2007)** categorises the possible issues when playing as Mana screw (too few mana), Mana flood (too much mana) and colour screw (no Mana of the desired type). Up to a certain point, these problems can be mitigated by proper mulligan decisions and by tweaking the deck with Mana considerations in mind. Even so, everyone runs into Mana trouble sooner or later.

Mana screw happens when lands drawn are considerably lower than the ratio of lands to spells that your deck list would suggest. Alternatively, you can be forcibly put in such a position if enough Mana sources are destroyed.

Mana flood happens when lands drawn are considerably higher than the ratio of lands to spells that your deck list would suggest. Mana flood is a direct opposite to Mana flood, but both issues can be highly problematic during the game, and thus, many considerations are taken in deck construction to prevent them. For Mana screw, players usually include a disproportionately high ratio of lands to spells considering the average Mana cost: Even if the average Mana cost on a deck is 2, usually the plan is to have three lands by turn three. This way, both higher cost spells are accessible, and this serves as a statistical buffer to minimise Mana screw. To compensate for this, players often include cards that benefit from having more Mana than usual and thus mitigate the problems of Mana flood.

Colour screw happens when the types of lands drawn do not allow you to cast the cards in your hand. Like Mana screw, this can also happen if enough Mana sources of a specific type are destroyed. This is one of many similarities it has with Mana screw, but there are also notable differences:

- You can still play some cards, even if not all.
- Your opponents do not know which cards in your hand can or cannot be played, which can lead to bluffs and some player agency even if options are limited.
- While Mana screwed, drawing a land gives access to only one higher-costed cards, but when Colour screwed, drawing the land you need might give you access to the very best cards in your hand.
- When Colour screwed, fewer draws help your situation. For example, drawing an Island and not a Mountain.

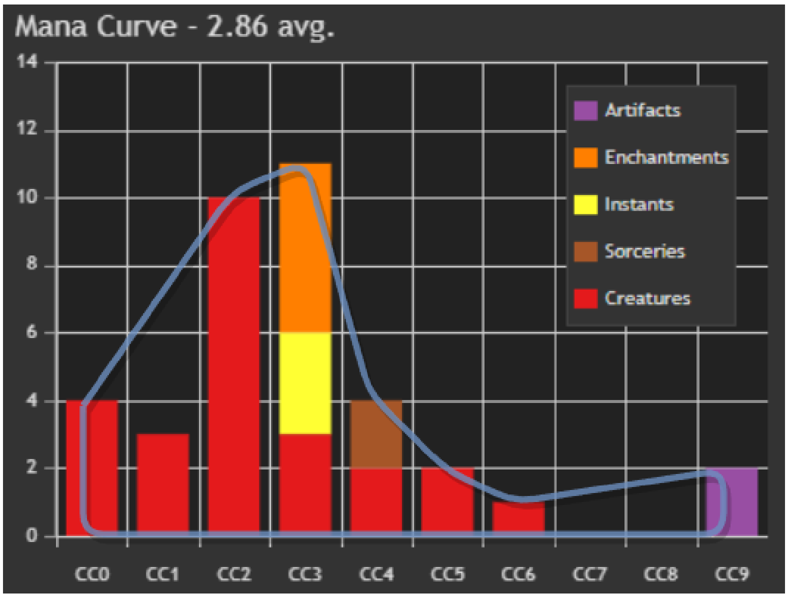
Overall, being Colour screwed is a less severe position than being Mana screwed (even if drawing out of it is harder) and thus it is not as disrupting. Additionally, considerations can be taken during deck construction to mitigate this issue like reducing the number of colours of a deck, taking out hard-to-cast cards that require many specific Mana types and including multiple Mana sources. **(Cunningham, 2007)**

All these resource issues are a result of statistical probability and not having a proper distribution of Mana costs in the cards of a Magic deck, what is known as a “Mana Curve”, says **Lewis (2017)**. If you group the cards by Mana cost from left to right, they create a graph showing how many cards of each Mana cost the deck contains. Even if every deck is different, the vast majority will have the peak of the curve in the middle, between 2 and 4 Mana cards, with a bias towards lower costed cards as they can be played earlier and more easily, and less high costed cards since they are harder to play and they can clog your hand.

This curve, shown in figure 15, resembles a bell curve (hence the name) and determines the flow of a deck throughout the game. If it’s not balanced, the deck will not be able to play and cast spells every turn.

**Figure 15**

*Mana curve in a 60-card deck*




Note. This deck wants to establish dominance early on, and finish the game with a few, very expensive cards. Own work.

When considering if you should add a new card that does not match your deck's colours, you might think that the difference of it having one or two Mana symbols is inconsequential, but mathematically there is a huge difference between drawing one and drawing two Mana sources of the colour you need. You need nine to ten sources for that colour instead of the five or six needed to pay only one Mana symbol consistently. So, unless you include cards that allow you to fix your mana, you will need more lands than what you are able to use effectively in your deck. Additionally, the lands you are including for the new colour will occupy space and hinder your ability to implement your already established strategy. Let's say you want to create a land base for a 40-card deck. You count all the Mana symbols in all your cards and you see that out of 25 of them, 18 are blue and 8 are black. This is about a 70:30 ratio and, as a result, your lands should reflect it: a good starting point would be to include 11 blue and 5 black sources. This is a general rule to create decks that has proven to be consistent, but if you have many low-costed cards of one colour you may consider skewing towards that colour in your Mana base to improve your opening hands and early turns. Another thing to consider is the effect of the cards in your deck: if you include cards that allow you to generate Mana or draw more cards, you can reconsider your land ratio and count to play those cards as early as possible **(Lewis, 2017)**

In order to identify the key factors that affect the Mana curve and land drops first we need to understand the deck's goals and win conditions. Fast decks will prioritise the early turns and thus have a greater density of two and three cost cards, while defensive decks might contain greater amounts of four and five cost cards than average. With this in mind we can create a Mana base and figure out how many lands we need: There are decks that only need two or three lands on the field to work, while others need to ensure that they play one land every turn in order to afford their expensive spells. If your deck is trying to play a four Mana card on turn four every single time then it will require 24-25 lands out of the 60 cards in the deck, but if you want to play a six Mana card on turn six consistently you will need around 27 lands so you can play one every turn.

The main strategies in the game implement their Mana bases differently, according to how they want to play the game:

**Aggressive decks** tend to include fewer lands than average since their Mana curves are going to peak early on. Most play around 20 lands since they can play the majority of their spells with only three mana. Since these decks want to pressure their opponent from turn one, having a third of their deck as Mana sources is a good balance between having enough resources to play the game and having enough fuel to blast off their opponent before they start playing more expensive and harder to deal with threats.

**Mid-range decks** usually want to hit the four Mana mark to set the stage for their mid-costed spells. Most play around 24 lands but it’s not uncommon to see 25 or 26 lands if they include unique abilities that synergize well with the rest of the deck.

**Control decks** are willing to stay in the 26 to 27 lands range to make sure they can play lands almost every turn. This usually results in slower hands filled with lands, but they compensate for this by casting strong expensive spells that stop their enemies on their tracks, and then taking control of the game with their superior access to resources.

**Combo decks** unsurprisingly are all over the place, and it all depends on the combination of cards they are trying to assemble. When the entire deck is the combo, they usually include low land counts, so they draw more useful spells and less lands. Some decks that rely on a two-card engine tend to include high land counts so they can afford more spells that protect their combo. If the deck can generate Mana through nonland cards, you can afford to have an extremely low land count and still have a functioning deck, allowing you to accelerate your Mana generation in the early turns and then being able to play large threats earlier than your opponent. In some extreme cases, there have been decks which include no lands at all, and some that only include lands. **(Lewis, 2017)**

These two authors take an in-depth look at the issues with the economic system in one of the most influential card games ever created, Magic: The Gathering. While the analysis is mostly about the game’s economy, it also applies to the vast number of games that have been influenced by Magic since it has defined how modern TCGs and card games are made.

Both the focus on the definitions and origins of the problems by **Cunningham (2007)** and the focus on implementation and strategy by **Lewis (2017)** are two sides of the same coin: The economic systems of card games are one of, if not the most important aspects of their design, and a complex economic system creates gameplay with massive depth and room for strategy. But, when these systems fail, the game can become borderline unplayable, creating some of the best and the worst moments the game can offer.

# Planning and Methodology

## Planning

The thesis starts with establishing a clear set of problems to focus on and defining objectives which are appropriate to the theme and focus of the project, while being viable in the limited time available to finish the thesis. Due to this, some objectives were considered optional in the first stages of the thesis, and would be completed only if there was enough time once all the mandatory objectives were finalised.

With this initial estimation of objectives, two parts of the thesis were defined: The theoretical part and the practical part, where the theoretical part includes all the research, theoretical framework and analysis of the current state of the art in resource management in card games, and the practical part refers to the implementation of a practical prototype of the theory.

The theoretical part of the thesis starts with research on sources, authors and documentation of the state of the art in resource management game design, specifically centred around card games. More information about this research can be found in Annex 3. Since the focus of the project is narrow and documentation is scarce, the research was done top-down, starting from resource management in general, then applied in the context of game design and finally specifically tailored to card game design. Even if the focus on research was at its highest at the beginning of the project, new sources of information have been added throughout the course of the thesis and the theory has been expanded accordingly.

With the initial research done more than 40 sources were gathered and sorted by a series of criteria such as year of publication, academic relevance (thesis were prioritised over forum posts, for example), number of citations, relevancy to game design and relevancy to card game design, among others. Once filtered, the most relevant sources to the project were explored in-depth, gathering quotes, information and fragments which then were re-written, contextualised and combined to create the different sections of the theoretical framework. Additionally, all figures necessary were created to support the theory.

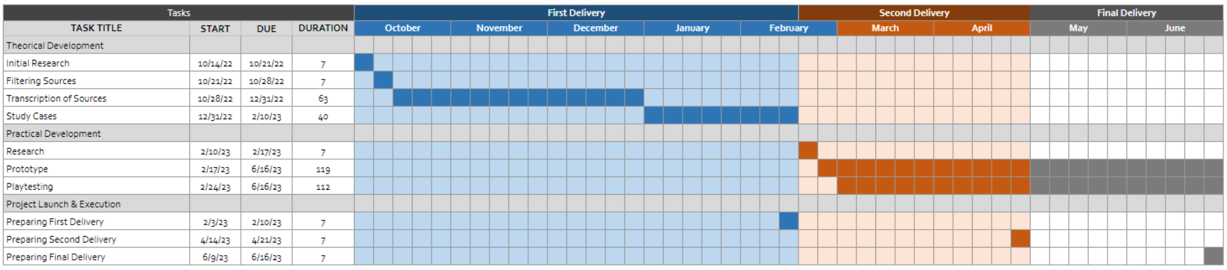
The next step is to contrast the theory with the current state of card game design through four study cases, selected to highlight the different theories elaborated in the theoretical framework and how they are applied, explaining when they work and when they don't.

With all the concepts developed in the theoretical framework and the additional context derived from the study cases, the natural progression of the project leads to applying them in a practical demo by creating a prototype card game designed around resource management.

The Initial planning of the project distributes all these tasks along the duration of the thesis, as shown in figure 16.

**Figure 16**

*Gantt Diagram of the project*




Note. Initial distribution of tasks, estimated in weeks. Own work.

## Study Cases

In order to contextualise the theoretical framework with real world examples, four games have been selected as study cases, and will be analysed using 20 analysis variables directly related to the theoretical section of this thesis.

The study cases chosen are:

- **Magic: The Gathering**: Since 1993, Magic has defined how collectible card games work, both mechanically and logistically. As a study case, Magic serves as a point of reference of the origin and inspiration of almost all modern collectible card games. If Magic does something, most TCGs do it too.
- **Hearthstone**: Heavily inspired by Magic, Hearthstone aims to bring the tabletop feeling of card games into the digital world, serving as an example of how the card game design has evolved over time and what card mechanics can be featured in a digital format that would be impossible to implement in a physical game.
- **Yu-Gi-Oh!**: Originally an invented game from a Manga comic book, Yu-Gi-Oh! has consolidated as one of the most influential and popular collectible card games ever created. Unlike Magic and other Magic-like games, there is no Mana or another non-card resource needed to play most cards, they are effectively “free”. This brings a myriad of possibilities and issues that make it unique.
- **Poker (Texas Hold 'em)**: As the most known card game in the world, Poker brings the perspective of classical, non-collectible card games. Among all the number of variations, Texas Hold ‘em has been chosen for its extensive popularity and the intricacies of its use of partial information. Additionally, Poker serves as an example as it is designed around card and non-card resource management (chips).

The 15 variables used to analyse the study cases are: Card resources, non-card resources, the progression resource, currencies, sources, sinks, converters, traders, strategies, deckbuilding, player interaction, information, generosity, resource progression and feedback loops.

## Card Resources

Magic features a high diversity of card types, but the game is centred around two big categories: Land cards and Nonland cards. Land cards are the main resource used in the game since they generate Mana, the energy needed to play nonland cards. By themselves, lands are (mostly) useless, and represent a compromise for the player: They are essential in order to play, but you want as few as possible since they don’t add value to your strategy by themselves in the vast majority of cases. Nonland cards on the other hand, are the cards that actually allow players to win the game and, in order to balance their power, the more powerful they are, the more lands needed in order to play them. Figure 17 illustrates their main differences.

**Figure 17**

*Land and Nonland card comparison*


Note. Some land cards include rules and effects too, but the basic lands upon which the game is designed are only used to generate mana. Own work.

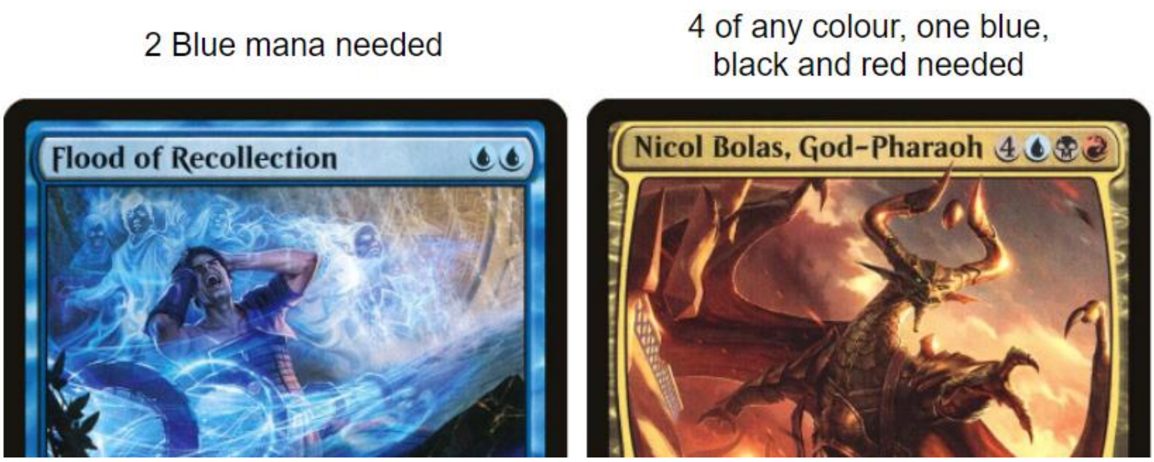
Among nonland cards the main types are instants and sorceries (one-time effect cards), creatures and Planeswalkers (minions that fight for you) and finally artefacts and enchantments (continuous effects that stay on the board).

Additionally, lands have limitations and types. Specifically, you can only play one land card per turn, slowing the escalation of powerful effects and making cards of all costs relevant at different points in the game, and Lands are divided into 5 types: Plains, islands, swamps, mountains and forests, each generating Mana of their colour and restricting effects that may be too powerful when played together. As shown in Figure 18, cards can require more than one type of Mana to be played, but having such cards represents an important decision for the player as they will need to include plenty of all the land types required in the deck in order to be statistically probable to play said card.

Having different land types and complex costs for playing cards allows for great diversity in strategies and decks, one of Magic's greatest strengths, but due to the high-volatility nature of card games and their reliance of randomness it can also become one of Magic's greatest flaws: The more Land types you include in a deck, the more probable it is to not draw the lands you need, and even if you minimise the odds by reducing the number of Land types, there will be occasions where only Lands are drawn or no Lands are drawn for many consecutive turns.

**Figure 18**

*Cost comparison between Magic cards*




Note. Some cards do not require any specific Mana colour to be played, this is represented with a number indicating the amount of generic Mana needed. Own work.

Hearthstone inherits a few card types from Magic, the most notable ones being creatures and sorceries (here called spells), but does not use land cards, instead using a non-card resource as cost in order to balance their power. The game also has a few unique card types: Weapons and secrets.
Creatures are cards that represent minions and are controlled by the player, they are the main card type present in the game and gameplay revolves around them. Spells on the other hand are one-use effects, usually meant to disrupt the opponent's strategy or to be combined with other cards. Weapons are cards that can be used multiple times and allow players to deal with creatures, and secrets are cards that remain inactive until a condition is met, and then their effects are applied instantly.

All these cards are separated into different pools by the class system. In Hearthstone, you have to select a class when building a deck, which gives access to a unique ability and a specific set of cards. Unlike Magic, here the different colours of Mana that define the decks are transformed into a decision that comes before building the deck, restricting combinations of cards that would otherwise be too powerful when played together.

There are three main card types in Yu-Gi-Oh!: Monsters, Spells and Traps.

Like Magic and Hearthstone, the Monsters represent minions that stay on the board and fight for you, Spells represent one-time effects and Trap cards are, as the name suggests, effects that remain hidden and take one turn to be used, but can be activated at any time to surprise your opponent.

Playing Monster cards can be done in a wide variety of ways:

- They can simply be played from the hand to the board without any cost, this is called a Normal Summon and can be done once per turn only
- If the Monster's level is five or six, they require you to remove one lower-level Monster from your board in order to be played. If the level is seven or higher, two monsters will have to be removed from your board. This is still considered a Normal Summon and is limited to once per turn.
- Monsters on the board face-down can be turned face-up.
- Special summons, which only occur due to game mechanics, card effects or Summoning conditions, for example a Monster that cannot be summoned normally and requires to

have no Monsters in play. Special summons do not count towards the one Normal Summon limit.

Spells and traps can be played freely without restrictions, making card advantage a key part of Yu-Gi-Oh! strategy. In most card games, cards are the main resource and obtaining more is a top priority, but this is dramatically more relevant in Yu-Gi-Oh! since it does not only allow players to choose the best card for the situation, it often allows them to play them all, often winning on the spot. For this reason, drawing cards is usually done under heavy drawbacks.

This represents an extremely limiting design restriction for the game, since drawing cards is the most fundamental action present in card games and Yu-Gi-Oh! just can't afford to let players do it without repercussions or conditions. But if players can't draw cards and are stuck with an ineffective set of cards in hand (or without cards at all) they need to have access to more. This problem has been present throughout all of Yu-Gi-Oh! history and is so rooted in the game's core mechanics that creating a definitive solution would require to change the game on a fundamental level.

Some Monsters, Spells and Trap cards may have conditions and/or additional costs, but these costs are part of their special rule texts and not a general condition that applies to all cards of the same type. For example, some Monster cards may require to have less Monsters than your opponent, or Spells that require the player to discard cards, etc.

Unlike the previous study cases, Poker is not a collectible card game, and is played with the same deck every time. There are many variants, but the most common is a French-suited deck consisting of 52 cards divided into four suits: Clubs, diamonds, hearts and spades. Each suit is formed by 13 cards, ten of them numbered and three court cards, Jack, Queen and King (often referred to J, Q and K respectively).

The game consists of rounds of betting, where up to five cards are displayed publicly and two cards are dealt to each player. Each player seeks the best five card poker hand from any combination of the seven cards, and the best combination wins the bet of the round.

The combinations, ranked from worst to best, are as follows:

- High card: The highest value card. The value of the cards, from lowest to highest is: 2, 3, 4, 5, 6, 7, 8, 9, 10, J, Q, K and 1.

- Pair: Two cards with the same value
- Two pairs: Two combinations of two equally-valued cards.
- Three of a kind: Three cards with the same value.
- Straight: A sequence of five cards in increasing value. For example, 8, 9, 10, J and Q.
- Flush: 5 cards of the same suit.
- Full house: Three of a kind and a pair.
- Four of a kind: Four cards of the same value.
- Straight flush: Straight of the same suit.

Due to the low value of individual cards and the high value of card combinations, the value of specific cards changes dramatically from game to game, and sometimes a low-value card can be the difference between a weak combination and a strong combination that wins the round.

In all of these games the deck itself is not only a convenient way to group the cards, but also a key element in card management since every card drawn and played is one less resource in a limited pool visible for all players. This goes to the extent that, when playing with very good players, counting the cards played and the ones remaining in the deck is a key skill that will significantly impact your chances of winning. Unlike Poker, where the deck is the same for all players every game, in collectible card games players can customise their deck, and is not uncommon to see effects that allow players to shuffle cards spent back in the deck or discarding cards directly from the deck as a form of attack or as a heavy cost for playing certain cards.

**Non-card Resources**

Even if Lands are the core element of Magic's card cost, the system is more intricate that just having a required number of cards on the board: Land cards are useful because they produce a non-card resource called Mana, and with that resource cards are played, as shown in figure 19.

**Figure 19**

*Land creating Mana to pay for a card*


Note. The relevant element needed to play Aegis Turtle is one blue Mana. It is usually generated through Islands, but it is not mandatory. Own work.

This translation from card (Island) to non-card (blue mana) back to card (Aegis Turtle) is not just trivial and a way to make the game rules more convoluted, it has relevant gameplay implications. Specifically, Lands are not the only way a player can generate Mana, and both the colour and amount of Mana generated through Lands can be modified during the course of the game thanks to some card effects.

In order to generate Mana from a Land card, a player has to tap the Land (turn the card 90º). This is done to signal that the card has been spent and to avoid using a single Land multiple times during a turn. At the beginning of a player's turn, all their cards get untapped so they can be used again. Thanks to this, the Mana progression of a player who plays one Land each turn (the maximum under normal circumstances) is a linear progression instead of a triangular progression (at turn 4 they have up to 4 mana, instead of having 4+3+2+1 mana) preventing them from having access to very expensive cards too soon. At the same time, this incentivizes players to use all their Lands and play proactively, since they get replenished every turn.

Another key non-card resource present in Magic is life points. Each player starts with 20 and if they get depleted, they lose the game. This amount is key to balance aggressive strategies who seek to deal as much damage as possible in the early turns of the game with slower strategies that seek to control their opponents and win with a slow but steady threat while maintaining resource superiority. Life points not only represent how close to being defeated a player is, they are also a resource that can be interacted with, and spent if need be. Many cards and effects require spending life points in order to be played, and there are certain strategies that benefit greatly from having as few life points as possible, playing on a very thin balance between obtaining the most power from their cards and having so few life points that they get defeated with ease.

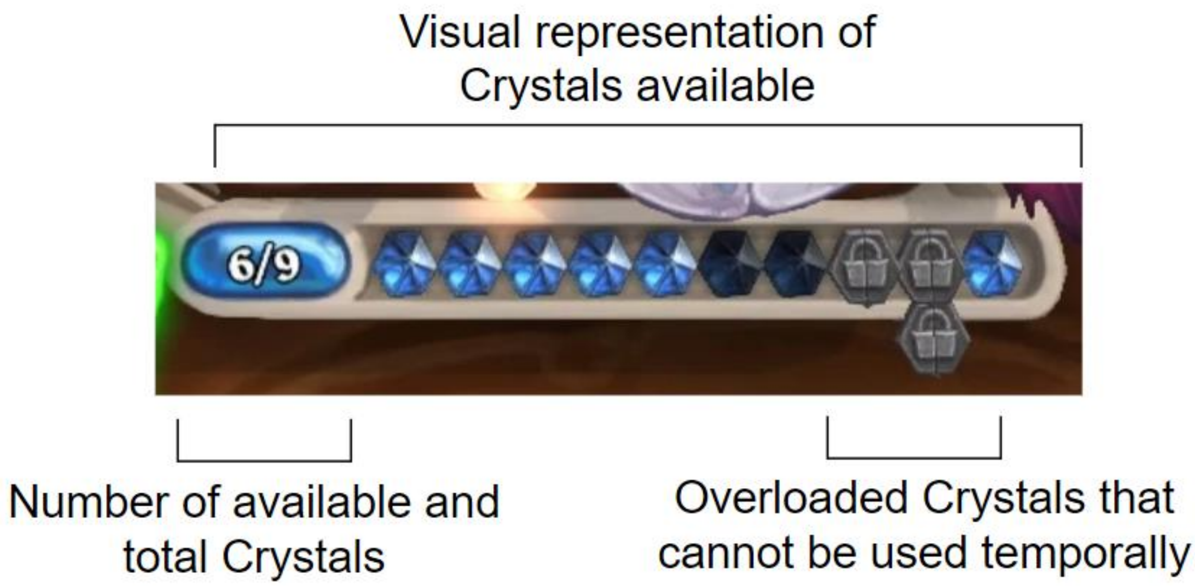
There are many more non-card resources present in Magic, but they are not part of the core rules of the game, and are part of specific card effects instead. They could be instrumental in one deck while that same resource may not even be present in any card of another player's deck. They are usually represented in the form of counters and are displayed with dice. Some examples of these resources are energy counters that represent the number of times an ability of a card can be activated, power counters that display the amount of power a creature has above their base stats, poison counters that may kill a player if they get enough of them, etc.

Hearthstone gets the concept of Mana from Magic and answers the question: "How can we make sure that players get one Land every turn?".

The solution they implemented is getting rid of Land cards altogether, and instead generate Mana with Mana Crystals. Each player gets one every turn up to a maximum of 10. This way, the edge case where a player does not get any Land cards never happens. This system has many upsides compared to Magic, but also has its flaws: There are no Mana types in Hearthstone, and because the decks are smaller and without Land cards, the strategies are usually more straightforward and predictable, with way less room for variance and deck customization. Another problem is that because Mana Crystals are guaranteed every turn, the differences between aggressive and slower decks are less pronounced, and all of them aim for almost the same Mana curve. There are two classes in Hearthstone that interact in unique ways with the Mana Crystal system: Druid has access to cards that allow them to generate Mana crystals earlier than their opponents, and Shaman can overload their Crystals with some cards, gaining access to powerful effects for a cheaper than average cost but losing access for one turn to some Mana crystals, as shown in figure 20.

**Figure 20**

*Hearthstone Mana Crystals*




Note. In the bottom of the screen, the total and available Crystals are displayed. When a Shaman card with Overload is played, some Crystals get locked temporarily. Own work.

The other non-card resource which the game is based around is health. Not only players have a limited amount of health points, but creatures have them too. Unlike Magic, when a creature is dealt damage, their health is not restored at the end of the turn. Thanks to the digital format, keeping track of the individual health points of each creature and player is not an issue, and this changes the game drastically: Lots of small creatures can deal with ease with singular strong creatures, and cards that can heal your creatures are potentially very strong, or sometimes useless. Players start with 30 health points and, once they reach 0, they lose the game.

Unlike most popular TCGs, Yu-Gi-Oh! does not follow Magic's footsteps and does not contain a Mana system. Instead, most cards can be played for free, without any cost or restriction. When an effect is too powerful, it is very common to see it paired together with costs like losing health points or discarding cards, because there are no more core resources players can interact with. In the case of health points, each player starts with 8000 and if they reach zero, they lose, but due to the fast paced and combo nature of the game, all health points are usually lost in a single turn, and battles of attrition are not common, so losing life is often a risk worth taking. The lack of a Mana cost in cards can create absurd situations, where a card idea that would be totally feasible and tweakable if need be in another game is absurd in Yu-Gi-Oh!, to the point that it has to be banned from play, as seen in figure 21.

**Figure 21**

*Card comparison between Magic, Hearthstone and Yu-Gi-Oh!*


Note. These three cards all have the same effect: They allow the player who plays them to draw two cards. Own work.

As seen in the previous figure, similar effects can exist in multiple card games. In the case of Magic and Hearthstone, these cards are not bad but don't see much play, since their effect is good but paying three Mana for them is a bit expensive, and the cost-effectiveness of the card is reduced when taking into consideration that the Mana could have been spent in playing another more proactive card.

But when we analyse Yu-Gi-Oh!'s version, Pot of Greed, we can see a card with no downside whatsoever. This card is not restricted by the "one Normal Summon per turn" rule, you can play it for free, and doing so leaves the player with +1 card advantage. Not only does this effectively reduce the deck size for anyone playing Pot of Greed, since drawing the card means playing it, and it replaces itself, but it also gives you card advantage in the process, and that could either mean drawing more Pots of Greed, prolonging the cycle, or drawing the cards that form your winning strategy, dramatically increasing the chances you can win on the spot. Yu-Gi-Oh! Simply cannot afford to let players use Pot of Greed, and thus it was quickly forbidden from all play, but this example shows how desperately needed is a restricting effect or cost for cards in a collectible card game.

Even if Poker is a card game, what it really is about is chips. Chips represent money, and managing it successfully is the key to playing Poker well. Even if you are playing for fun and no real-life money is involved, using chips is mandatory for the game to make sense. Chips might seem a currency at first since they represent a real-life currency, but in the context of the game of Poker they are a resource, since they have uses by themselves and, more specifically, they represent how close a player is from defeat: Once a player has no more chips, they lose the game. **(Kraj, 2021)**

Since Poker is usually played with chips representing real money, games often end before someone loses all their chips, but even in that case chips are the main objective, and having more chips can be leveraged for a considerable advantage.

All round players have to bet in order to keep playing, and bets can be increased by every player if they choose to do so. This is usually done by players with strong card combinations to try to maximise their chip earnings for the round, but since cards are hidden until the end of the round, it can also be a bluff by a player with a weak combination that is trying to scare other players from betting in and surrendering, earning all the chips that have to be bet by default in the process.

### The Progression Resource

Magic: The Gathering, Hearthstone and Yu-Gi-Oh! All have the same progression resource: Player health points. More specifically, they have an inverse progression resource, since instead of being a resource that has to be gathered to win, the less you have the closer you are to defeat.

In most cases, the “win condition” of a deck (the card or combination of cards that in your strategy allows you to win the game) is usually a threat or series of threats that attempt to reduce your opponent’s life to zero. Sometimes this is done through early aggression that is hard to stop in time, or sometimes this is done by slippery threats that are hard to deal with and will win slowly by attrition.

But this is not the only way to win in those games. When a player’s deck is empty and they attempt to draw a card, in both Magic and Yu-Gi-Oh! They lose the game. In the case of hearthstone, they enter a “fatigue” state where they will receive cumulative damage for each card, they attempted to draw but couldn’t. This means that in all three games it is a viable strategy to deck out your opponent and, in this context, the number of remaining cards in a deck is also an inverse progression resource.

In the case of Poker, the chips are also an inverse progression resource, since having no chips means you can’t keep playing the game. What separates poker from the previous games is that the progression resource is limited, and all chip exchanges are zero-sum, and if one player is left without them, this means that the rest of the players have obtained their chips.

**Currencies**

Due to the nature of card games, it's uncommon to find currencies in such games. In most cases, the elements that the players interact with are useful by themselves and connect with the other systems in unique ways. This is mainly because unlike digital games, card games are played with limited resources, so dedicating cards or another similar element to track currencies not only is expensive in a literal and figurative sense, but it is also easily confusing for players.

It is not a surprise that the only game in the list of study cases that contains currencies is the only digital one: Hearthstone. In this game, there are two main currencies whose final objective is to be exchanged for cards. The currencies are:

- Gold coins that can be used to buy card packs and to gain access to events that reward card packs and individual cards. This currency can be obtained playing games or bought with real money since Hearthstone is a Free-to-play game.
- Dust, a currency that aims to replace the act of trading physical cards in a digital context. It's used to exchange any card for another through a very steep exchange rate.

**Sources**

The main Source in all card games is the deck of cards. Either shared or each player with their own deck, they provide cards for players, allowing them to play. When a game contains a single deck of cards, like in the case of Poker, there is usually a dealer who is in charge of distributing cards to players. Dealers can be the players themselves and the player with the role can change along the game.

The cards themselves can also be Sources, as shown in figure 21, cards can provide more cards, health points or any other resource needed in the game, like in the case of Magic, where some cards are the Source of mana.

In some extreme cases, the cards you own can be Sources for other players, since some strategies benefit from giving detrimental cards to opponents, or some effects may allow players to steal cards from an opponent’s hand, board or even deck. Cards with effects like this can be seen in Magic, Hearthstone and Yu-Gi-Oh!.

The chips in poker have to be bought by players before the game, since they represent real money, and during the game the Source of chips are the players themselves, since winning rounds earns you chips from all players who have bet during the round.

**Sinks**

In the vast majority of cases, the Sinks in card games are the cards themselves. The two main ways they remove resources from the game are in the form of costs, requiring resources to be played, and by specific effects of certain cards that allow players to get rid of their opponent's resources. In the case of Magic and Hearthstone, cards have costs so Mana is constantly being removed from the game, but sometimes cards also require losing life or discarding cards as additional costs.

Yu-Gi-Oh! Does not have an implicit Sink by default in their cards, but there are plenty of cards with cost in the game nevertheless. Most of the time, these Sinks remove health, other cards from the board or cards from your hand and deck. In the case of monster cards with level above four, they require lower-level monster sacrifice in order to be played. Even though Yu-Gi-Oh! often circumvents the lack of costs by requiring specific conditions in order to play cards, the combination of lack of default costs with not having a Mana-like resource makes their Sinks very similar and results in a very small design space when interacting with resources.

Another type of Sinks instrumental to many card games are those defined by the rules, usually in the form of conditional costs or an upkeep cost that drains resources from players every turn. An example of this would be the small blind and big blind of Poker (present in Texas Hold 'em and other variations) that force players that want to keep playing to bet every round. Another example of these types of Sinks would be the hand limit present in Magic, Hearthstone and Yu-Gi-Oh!, that forces players to discard cards at the end of their turn if they have more cards in hand than the hand limit. This is done to encourage proactive play instead of hoarding resources, and to prevent players from accumulating a critical mass of cards that could lead to oppressive play patterns.

**Converters**

In the context of card games, converters are very rare to find, since the vast majority of resources are concrete and tangible (cards, chips, dice), and converting implies destroying the old resource to generate a new one, instead of maintaining the total amount of resources constant.

Some games like Magic contain cards that act as converters, allowing to exchange intangible resources like Mana from any colour into another. This is usually done at a steep cost and results in an overall Mana loss to prevent abuse.

### Traders

The most common root cause of balancing issues in card games or even resource management games in general is the ability to exchange one resource into another too cheaply. The moment this is possible, a myriad of problems appears: When exchanging resources is too cheap, if one resource is easy to obtain, all resources are easy to obtain, which breaks all systems related to them. This is especially relevant with the progression resource, which in this context would mean that any resource can win the game since they can be exchanged with ease.

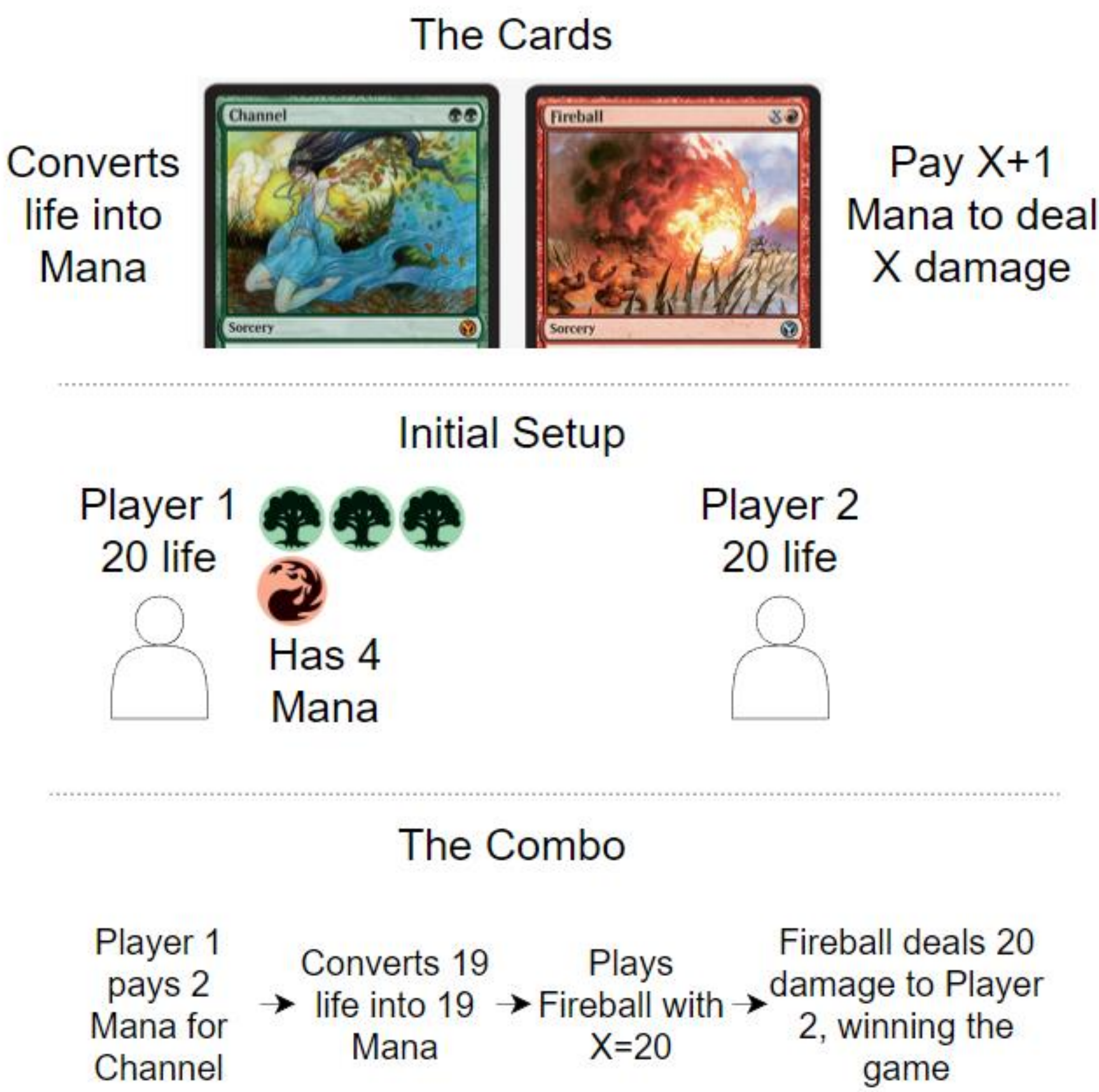
One example of this problem would be the classic Channel Fireball combo present in Magic: The Gathering, illustrated in figure 22.

As seen in the figure, the issue comes from exchanging two resources with excessive ease (life for mana). This breaks the cost system of cards since players start with 20 lives that with Channel can be converted into up to 19 mana on a whim. This is not the most powerful or abusive combo present in Magic or other card games, but serves to illustrate the problem of extremely cheap conversion (this also explains why pot of greed is so strong in Yu-Gi-Oh!, illustrated in figure 21, since it allows to exchange one card for two, a ridiculous conversion rate). In fact, if we analyse the most powerful and oppressive cards in almost any card game, they all have the same problem: they allow to exchange too few resources for too many (a card and usually a cheap cost for the powerful effect they provide).

Virtually every card acts a trader when played since they represent an exchange: The player expends one card for an effect, leaving constant the total amount of cards in the game. Later on, they may stay on the board and act as a Source, Sink, etc.

**Figure 22**

*Channel Fireball combo*




Note. Players start the game with 20 life points, and thanks to a card that generates three green mana, this combo could win the game before Player 2 played his very first turn. Own work.

**Strategies**

In the context of trading card games, where decks can be customised, there are four main archetypes that all decks fall into. These archetypes are:

Aggro (also known as aggressive or burn) decks aim to end the game as fast as possible by overwhelming their opponents with early threats before they get a chance to respond. Aggro decks are usually disregarded as “low skill” and an easy strategy for new players, but sequencing your threats appropriately according to your opponent’s strategy and how they aim to deal with your cards is a fine balance that leaves no room for mistakes. After all, the less turns you aim to play, the more important it is to execute each turn flawlessly.

Control decks are usually considered the antithesis of Aggro. They aim to slow down the game and prevent their opponents from establishing their strategy, often winning the game with expensive threats that are hard to deal with. A deep understanding of the metagame and how each deck aims to win is crucial to pilot a Control deck properly.

Midrange decks sit in-between Aggro and Control. These decks are often aggressive in nature, but aim to first establish a strong resource base before starting to threaten their opponents with medium-costed cards. These types of strategies are often very flexible and can play defensively and slow down Aggro decks and also ramp up the pace and win Control decks before they can establish their defences.

Combo decks are decks that aim to win the game by combining certain effects that synergize together to create an unstoppable threat. Unlike the previous categories, Combo decks can be both extremely fast and extremely slow, depending on the card combination they aim to exploit and how many defensive elements they incorporate into the deck.

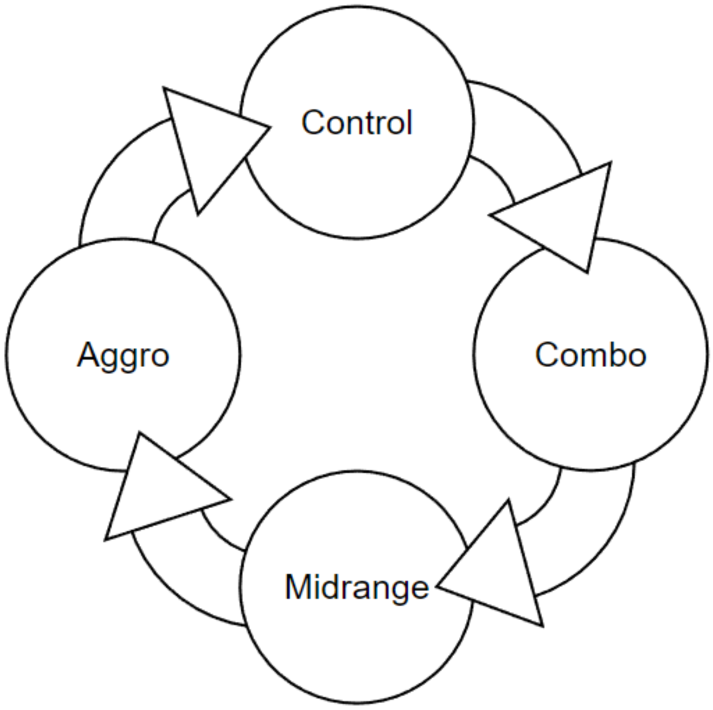
Even if each deck is different and there are countless ways to incorporate these strategies, the metagame usually revolves around the following formula, illustrated in figure 23:

- Aggro beats control since they can attack faster than control can defend.
- Control beats combo since they can disrupt their winning strategy.
- Combo beats midrange since midrange is not fast enough to outpace their combo and does not contain enough defensive measures to disrupt it.

- Midrange beats aggro since they can build defensive measures fast enough to keep up with their pace, and aggro cannot deal with their threats.

**Figure 23**

*Metagame Wheel*




Note. The arrows indicate favourable matchups for each strategy. Own work.

These categories are not mutually exclusive, and the best decks will aim to include various of them so they can respond to their opponents better. If an Aggro deck incorporates combo elements, they are theoretically able to deal with every other strategy in the metagame, but combining strategies properly and building a consistent enough deck is extremely complicated and, even if can be done, there will always be certain cards and combinations that will be able to deal with the deck. Additionally, these categories are a framework to define decks, but in practice each combination of cards is different, and each has their pros, cons, and ways to be dealt with. For example, two different aggro decks might have completely different win rates against the same control deck.

In the case of Poker, the strategies revolve around psychology and statistics. A skilled poker player might know at any time the odds they have to win the round, taking into consideration their current combination, the best combination they could get with the cards left to be revealed, and the combinations that their opponents might come up with. But, all of that can change when adding to the mix bluffs and pure randomness. A player might have a 90% chance to win at a certain point, but there is always a degree of uncertainness that has to be taken into consideration.

Even if Yu-Gi-Oh! is thematically similar to Magic and Hearthstone and also features a creature-based gameplay, the strategies in this game are drastically different due to the nature of its treatment of resources: In Magic and Hearthstone players aim to control the progression of mana and establish and advantage based on it, but in Yu-Gi-Oh! there is no such thing, players are ready to go for the win from the very first turn, and it does happen often. Winning in a single turn is not only common, it is expected. In fact, what differentiates normal strategies from the best is not if they can do one turn kills, it is how consistently they do so.

Thus, Yu-Gi-Oh! gameplay is based around crazy combos and interrupts that prevent them, it's a game about cat and mouse and limited information, where both players have to sequence their actions precisely, playing cards aiming to bait their opponents to waste their interrupts in non-crucial threats to secure that their main threats pass through and take over the game.

**Deckbuilding**

In the case of Poker, the deck is the same every game, so there is no deckbuilding involved, but in collectible card games there is a high emphasis on deckbuilding in their design.

Building decks well is one of the hardest things to do in a card game: Knowledge of statistics, creativity and a deep understanding of the game and the metagame are needed to create strong decks. Even if lots of concepts and skills in deckbuilding can be translated from one game to another, all the nuances of a game's design have to be considered and thus deckbuilding changes from game to game.

Magic is the only game in the list of study cases that requires players to dilute their deck with Lands. This forces players to choose the density of resource-oriented cards and payoffs in their deck beforehand, and shapes how the deck will respond just by sheer statistics. Decks usually are composed of 40% of Lands, which means that twenty four out of sixty cards do nothing proactively by themselves. This may be just fine, too much or too little, entirely depending on your strategy, the average cost of your deck, and if the deck includes Nonland cards that can generate Mana.

If the decks include cards that require more than one Mana colour, the Lands have to be reconsidered, further complicating the deckbuilding process. Including more Mana colours is in most cases a trade-off: The deck gains access to a wider variety of effects, but it will be statistically more probable to get stuck without the mana needed in any given turn, and thus multi colour decks feature a higher density of cards that allow them to get the Mana they need.

Hearthstone players are faced with a decision before they consider what cards to include in a deck: They have to choose a class that will define the card pool they can use to build the deck, and will give them a unique ability during the game, the "hero power". Since Mana in hearthstone is generated automatically every turn, there is not a dilemma of how many Lands to include in a deck, and thus deckbuilding is simplified and all decks are similar in how they distribute their Mana curve.

When building a deck for Yu-Gi-Oh! there are two main considerations players must make: Consistency and metagame. Each deck aims to set up their strategy and try to win on the spot, but usually only a few cards in the whole deck allow this. Including alternatives so different lines of play can be assembled or cards that allow players to search for their win conditions is crucial to make sure that a deck works and does not get stuck with a handful of cards that cannot win. The other consideration is that the game is not played alone, there will always be an opponent with a strategy, and knowing how to stop it is crucial to prevent them from winning before you do. Choosing the right interrupts and in the proper amount so they don’t impede developing your strategy is crucial and requires extensive testing and fine tuning.

**Player interaction**

Although most cards and strategies focus on your own resources, interacting with your opponents is a key part of gameplay and what makes the games feel like a social interaction instead of solitary experiences. In the case of Magic, Lands are such a key component in gameplay that interacting with them is expensive, often reserved for late-game effects to prevent players from denying their opponents from playing. Most of the interactions are centred around nonland cards to create a game flow where threats and answers are exchanged but resource progression is somewhat constant. In certain scenarios Land destruction is a viable and powerful strategy, but often requires a specific metagame where interacting with lands in key points in the game is extremely effective.

In Hearthstone, Mana crystals are very hard to interact with, since tampering with them is extremely disruptive to the flow of the game. Still, there are two classes who have unique ways to interact with them: Druid is able to create new Mana crystals, exchanging a passive early game with an accelerated resource progression. Shaman is somewhat opposite to Druid by virtue of gaining access to powerful effects earlier than average, but temporarily disabling Mana crystals the following turn, exchanging an aggressive early game with a slowed down resource progression.

Yu-Gi-Oh! features trap cards that are played face-down and can be activated upon specific conditions. Most of the time, trap cards are meant to stop specific threats that are integral to their opponent’s strategy, preventing them from winning on the spot. This creates a bluff-heavy metagame where the order in which threats and answers are played is extremely crucial. Even though cards can be interacted with, dampening or even stopping an opponent’s resource progression is extremely difficult, since there is no Mana equivalent that can be interacted with and the only real limiting factor is the number of cards in each player’s hand. This means that interacting with hand cards is an extremely powerful effect and thus is heavily limited and always accompanied with severe drawbacks.

In Poker the interaction is a key part of the game, but the ways that it can be done mechanically are very limited: Players can only increase their bet. When doing so, players are forcing others to gamble more resources to match their bet or retire to minimise their losses. This does not impede players from interacting in non-mechanical ways by virtue of reactions, comments or simply by pretending to play in patterns, and this information can be used to try and predict their play.

### Information

A key component of strategy is the information a player has about them and their opponents. Each card played is a clue about that player’s game plan and how it should be approached, and some card effects can help gather more information: In Magic there are plenty of cards that allow players to see their opponents’ hands, decks and their own deck to see what each player is going to draw. These effects are common because they have a price to be paid, and because there are plenty of other cards that mitigate or negate their effect (you may know what card your opponent is going to draw next turn, but if they shuffle their deck that information is effectively lost). These kinds of effects offer a design paradox: The more of them a game has, the more they can be introduced, but if a game has very few, they have to either never add more or add a lot of them together, since having asymmetrical access to information leads to very oppressive play styles and strategies.

Hearthstone offers way less information-related effects because the game contains very few cards that allow players to interact with said information, but there are two key elements that experienced players will look up to: Since it is a digital card game and players can’t just shuffle the cards in their hand, keeping track of what card is played and for how many turns has it been on an opponent’s hand is a sneaky way to keep track of their resources, and gives clues of what effect that card might have. Another key element in the information game in Hearthstone are Secret cards. Once played, they remain inactive until a condition is met, and since there are a few secrets available to each class, players can have an educated guess of what secret is played, allowing for bluffs and counterplay even if the information is limited.

Yu-Gi-Oh! features Trap cards that remain face-down until they can be activated when a condition is met, often intended to stop key cards from an opponent. In a game were playing all the threats in a player’s hand can be done as early as the very first turn, knowing which cards they have and which one needs to be cancelled is such a crucial information that cards that reveal Traps or even player’s hands are almost forbidden: They break the main interaction between players and thus the game can’t afford to have them, at least not without extremely severe drawbacks.

In the Texas Hold ’em variant of Poker players are dealt only two cards, and then each betting round new cards are publicly revealed, until five cards are shown and combinations can be made with them. This means that information has a price, and even if a player's hands are only shown at the very end, the possible combinations each player might do are slowly revealed through each betting round. Additionally, how each player reacts to the revealed cards might or might not be a clue about their combinations, as well as how they bet. A new card is revealed and suddenly a player increases the bet dramatically. Will they have a strong hand? The only way of knowing is paying the price.

**Generosity**

In the case of Poker, the Source of cards is constant, and new cards are added to the table in each betting round, but the bet necessary to continue is up to the players and how much they increase it, thus generosity is not fixed. At the same time, the higher the bet, the higher are the earnings for the winning player, generating a prisoner's dilemma situation where all players can raise the bet or bail, but they only want to raise if they are going to win the round, which is never certain.

In Magic, the generosity of a deck is predefined by the player during the deckbuilding process, and the more lands are included, the higher is the ratio of Sources/Sinks. During the game, Lands are accumulated on the board, generating a resource progression that changes the generosity over the turns. At the beginning of the game players have no Mana Sources, and at the end they have plenty to cast almost any card in their deck. Regarding card draw, players obtain seven cards at the beginning of the game and draw one every turn, but Sources of cards can be increased in the form of playing effects that allow players to draw more cards.

Hearthstone has a fixed Mana progression, so not only players naturally draw a card each turn, they also get one Mana crystal too, up to ten. But not all players have the same generosity: the second player gets the coin, a card that has no cost and gives one Mana temporarily when played. This mechanic seeks to minimise the disadvantage of playing second by giving a one-time increase of resources to the player that gets to have less of them.

In Yu-Gi-Oh! there are no lands to include in the deck, and card draw effects are scarce and heavily restricted, so most of the time players have a constant ratio of Sources and Sinks. In the case of monster cards, if they are five stars or greater, they have a summoning requirement of sacrificing another monster, but most of the time cards can be played without spending any additional resource.

**Resource Progression**

As the game goes on, the value of resources changes and strategies have to adapt to the new state of the game. In the games where cards have cost, like Magic or Hearthstone, this is apparent in how powerful the high-cost cards are compared to the cheap ones. But each card played not only has a cost in Mana, they cost a card too, as redundant as this may sound. What this means is that the curve of power per Mana cost is not linear, since low-costed cards need to be relevant enough to justify spending a card so early in the game, and high-costed cards need to be stronger than average to justify the opportunity cost of just playing cheaper cards earlier instead. The land progression is also not linear: the first lands are extremely valuable as they will ensure that the first turns of the game can be played, but as the game goes on their value decreases dramatically, up to a point where it is usually the worst possible card that can be drawn. Since Hearthstone has a fixed Mana progression, drawing too many or too few lands is not an issue, but this also means that the curve of power per cost is different, and higher cost cards cannot be as powerful as they are in Magic, since eventually all players will be able to play them.

When we compare this to Yu-Gi-Oh!, we see that most cards are roughly of equal power, and the only cards that are clearly stronger are either banned from competitive play or are monsters of five stars or more, that require sacrificing monsters to be played. What this means is that by the second turn of the game, most players can access their most powerful cards in the deck, and sometimes can be done the very first turn, so the resource progression is almost flat.

There are cards that are by default better than others in Poker, but since combinations are better that any individual card is, their value is always relative. This value does not depend on how long the game has been played but instead on what resources are currently available for a player. What does change is the amount of chips each player has, and even if consistency and knowledge about statistics will yield a good return of chips in the long term, the amount each player has can change quickly in any round with high bets. In practice, this allows the players with more chips to bet higher because they can afford to do it, and because by doing so they are forcing the players with less chips to assume greater risks.

**Feedback loops**

Even if there are certain combinations of cards that create their own feedback loops present in Magic, Hearthstone and Yu-Gi-Oh!, all three of these games have at their core one big feedback loop: Drawing cards allows players to play cards, which keeps them in the game long enough to draw more cards, and so on and so forth. But, when the cards drawn do not allow the players to keep playing, the system collapses. In most situations this happens naturally just by virtue of one player outperforming another, or because of how the strategies interact with each other, finally reaching the conclusion of a game.

The problem is what happens when the very first cards drawn do not allow players to keep playing. Card games are by nature games where randomness has a high impact on gameplay, and even in the best decks there can be situations where the initial hand just does not work by itself. Each game has its unique twists to this problem, and also their own solutions.

In the case of Magic, this is especially relevant because of Lands. If no Lands are drawn (or not enough, or not of the colour needed) the opening hand renders unplayable, no matter how good the nonland cards are or how relevant they are in the specific matchup. In order to mitigate this problem Magic designers have implemented countless mechanics, measures and rules, the most notables being:

- Mulligan: The initial hand can be drawn again, with one card less as penalty.
- Diverse Land cards: new types of lands are constantly being introduced into the game, which try to mitigate their problems while not being too powerful to streamline deckbuilding and minimise the impact of colour restrictions. An example of this are lands that allow players to add Mana of multiple colours, but have drawbacks when being played.
- The inclusion of failsafe mechanics, like cards that can be discarded to draw others, often at a cost. These usually are secondary effects that are not the optimal use of the cards, but can salvage what would otherwise be losing game states.
- Large initial hands of seven cards out of sixty card decks.

Hearthstone streamlined Magic’s Mana system to mitigate most of these problems, and the inclusion of the Hero Power, an ability that all players have and does not cost any cards ensure that the vast majority of games are playable. Even so, these changes have to be compensated with worse initial hands (three cards out of a thirty-card deck, four for the second player) to prevent decks from being too consistent and making gameplay repetitive.

Unlike the previous two games, Yu-Gi-Oh! does not have all the problems a Mana system brings, but due to the nature of all cards being free and how prevalent combos are, the game simply cannot afford to let players mulligan their opening hand. This means that even if most hands are playable thanks to not having costs, when an initial hand cannot work by itself the game is basically over and there is nothing a player can do to prevent this, no matter how much effort was put in the deck building process.

Poker does not have an initial hand problem since all cards can be played, even if they don't result in the best combinations, so the main loop is instead focused around chips: Playing rounds requires chips, but to obtain chips you have to play rounds, this loop can only be sustained in the long run if the average return per round is equal or higher than the average bet. The only failsafe to this system is to buy more chips with real money, which creates a myriad of gambling-related problems for the game.

## Guidelines for designing Resource Systems

Having delved deeply into the current theories regarding resource system design and their different implementations in the study cases, a series of guidelines have been synthesised from the key principles and most influential concepts of the theoretical section of the thesis. These guidelines aim to provide a framework to consider when designing resource systems. The main focus of the project is card games, but due to the abstraction inherently necessary to create a game's economic system, these guidelines are meant to be applied to most resource systems regardless of genre.

### Defining the economic pillars

The first step towards designing an economic system is to first define the main aspects of the game that will be connected to the game's economy. Not every aspect of a game requires a resource system to work, but all the aspects that will be enhanced by having a resource system have to be considered in this step. For example, a game centred around exploration can use a resource system to spread resources throughout the game world, incentivizing players to explore by providing meaningful rewards.

### Defining the resources connected to the pillars

Having established the economic pillars of our game, the relationships between them can be mapped using resources, tying together the different aspects of a game's experience. Having too few resources that connect the pillars can be problematic, since players will find out the system that generates them more efficiently and all the others will be rendered obsolete, and having too many resources, while it allows for very tight balance of each individual resource and system, forces players to engage with every aspect of the game equally to maintain progress, hindering player agency and damaging the game's pacing.

### Defining the how to obtain and spend the main resources

With a clear definition of the resources needed and the pillars related to them, the next step towards designing a game's economy is establishing how, when and where resources can be generated, spent and exchanged. Having a clear understanding of the different Sources, Sinks, Converters and Traders present in a game's economy allows for a clear understanding of the flow of resources and how they appear and disappear, and which systems are affected in the process.

**Defining failsafes to prevent breaking points**

All game economies are doomed to fail, and while all the previous steps allow for designing a functional and engaging game economy, there may be extreme scenarios where players manage to generate virtually infinite resources, or end up completely devoid of them, rendering them unable to interact with any system in the game. To prevent these edge cases which are extremely detrimental to the game experience, it is crucial to implement failsafes that will make sure that players will be able to play the game, and enjoy it in the process. The most common examples are periodic Sources that make sure that resources are never perpetually zero, and negative feedback loops that will prevent players from exploiting a single system and obtaining too many resources from it. Every game will work differently and so the solutions will have to be tailored to its specific needs, but having an understanding of the importance of these systems will prevent most of the major problems related to a game's economy.

## Project Development & Playtesting

As defined in the project objectives, the final step of this thesis consists in the creation of a prototype game that will serve to validate the theory investigated and the design guidelines established.

After a brainstorming session, this prototype was decided to be a card game centred around resource management. The cards will work as segments of a conveyor belt in a factory generating, transforming and destroying resources in a chain shared between all players, so they will have to cooperate and compete against each other simultaneously.

The first step in the design process of the prototype consists of defining the economic pillars of the game. In order to do so, first the design pillars have to be conceived, defining the core aspects of the game. In this case, the game will be centred around cooperation and competition between players. These aspects of gameplay are usually opposite, but thanks to a resource system designed with the proper considerations they can be tied together to generate a back-and-forth gameplay that incentivizes them simultaneously. Once there is a clear understanding of the design pillars of the game, the economic pillars can be mapped around them with ease: If both competition and cooperation are to be incentivized, there can be a series of resources associated with playing around them, driving players into a delicate balance between playing in conjunction just long enough to get what they want, but with the consideration that if their opponents get too much out of it they will lose, generating complex dynamics in the process.

The second step is defining the resources connected to the pillars. Due to the nature of card games, the cards will be a resource in of itself that will have to be considered in the design process, and will have to be linked to most economic pillars due to their central role in the genre. Having a single resource related to cooperation and another for competition narrowed the design space too much and did not relate to the two pillars properly, leaving them disconnected. Thus, four central resources were conceived, designed to be obtained by playing in collaboration with other players but spent in individual goals, tying together the two pillars in the process. The cards will be the concrete, tangible resources that players play the game with, and the four central resources will be concrete but intangible resources generated through the cards. There are always abstract resources present in card games such as information, position on the table or deck order that even if they tend to not be considered by the game's mechanics, they have an impact on gameplay. Due to the focus on resource management in this demo, they will be incorporated mechanically into the game since they offer ample opportunities for rewarding both cooperation and competition. Adding other concrete, tangible resources represented as tokens or dice can be interesting, but since they blur the line that separates card games and board games, they will not be considered for this prototype.

The third step consists of defining all the sources, sinks, converters and traders present in the game. How will resources be generated, transformed and spent? Most card games have the deck as an unique source of cards, but this does not have to be always the case. In this demo, there will be two decks, one that contains most of the cards that form the game, shared between all players and focused on cooperation, and a secondary deck that will contain the recipes, cards that will act as sinks and as win conditions, determining the goal of each player secretly and enhancing the pillar of competition. This way, cards will be connected to the two pillars depending on their origin and the effects they contain. The source of the resources needed for the recipes will be the cards from the main deck, as well as the sinks: There will be cards that will generate them, and cards that will remove them, so gameplay is not just an incremental addition of resources but a back and forth between players, maximising the resources they need and maintaining low the resources they don’t need. The source of information about the cards in the deck, in the player's hands and even the recipes themselves will also be in the effects of the cards. With this configuration, the decks act as a steady source of cards to form the base of each player’s strategy, but as the game progresses the source and sink of additional resources will be through the cards themselves, as well as converters that will transform resources as players desire, allowing player expression and an incremental escalation of stakes as the game goes on.

Finally, some failsafes have to be put in place to prevent the game from becoming unplayable. The main issues this game faces are players being unable to play cards, players having too many cards and resources being generated too quickly. Since the only cards in the game that have a cost are recipes, if players are capable of drawing at least one card per turn they will be able to play the game at all times. The maximum number of cards they can hold has to be considered too, and this number is determined by how many cards they start the game with and how many cards they can draw on the first turns. The starting hand is set to four cards, giving enough choices for the players to develop a strategy, but not enough to consistently perform the same sequence every game. And since the maximum they can draw in a turn is three cards (one naturally per turn, and two by card effects) the maximum hand size is set to six, allowing players to play a draw two cards effect in the very first turn and not being limited in the process (four initial cards, one per turn and two by card effect, but spend one card by doing so) but limiting them in the next turns, preventing an excessive escalation of resources if they are able to play multiple draw card effects in succession. The resources that will be generated by the cards are at maximum two per card, and in most cases one card will provide one resource, and recipes require a total of nine, preventing players from winning before their opponents can even react. Another failsafe that prevents players from getting stuck with a hand they cannot play is by doing a “mulligan”, which is the option of re-drawing your starting hand, but this can only be done once to prevent the same strategies appearing too consistently.

With all these core elements of the game defined, the next step is to implement them and playtest them in order to iterate in the design, maintaining and enhancing what works and reworking what does not until all systems and mechanics are cohesive and create an engaging gameplay experience. In order to playtest the game, players from all skill levels have been selected and observed while they played the game, noting their opinions and thoughts through the game. Once the playtesting session concluded they were given a survey to convey their thoughts and opinions of the game. From the second iteration onwards, new playtesters were given the rulebook and instructed to read it and try to figure out how to play the game without input from the game designer, to validate not only the game but the rules too. Once they finished their first game, any doubts with the rules were explained and a second game was played in order to observe how their opinion of the game changes and validate how clear the game and its rules are.

To know how the game is played refer to the Game Instructions in the annexes.

### 1st Iteration

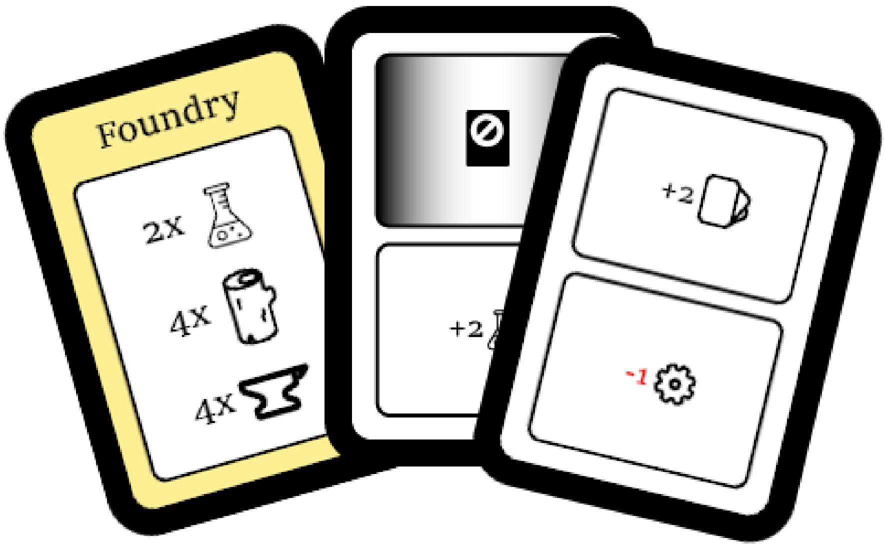
In the first iteration the outline of the game is defined, as well as the core elements and mechanics. Since this is the first version of a demo, nothing is set in stone and if playtesting shows that something does not work, there is plenty of time to change it and re-design the game if need be. The first ideas of the game after the brainstorming were to make the game about a shared chain of cards, in which all players can add effects in order to create, transform and destroy the resources that the chain interacts with.

The game has been designed following the guidelines for designing resource systems, and with them its economic pillars and ways to interact with them have been established. All the resources are designed to be equally valuable by means of the amount of ways to generate them and consume them, but every player will have their own recipe, so they will not be equally valuable for all players. As these ideas were fleshed into cards, most cards seemed to be too simple and uninteresting: The cards that had unique effects usually did not generate resources used by the recipes, but other cards or information, and the cards that generated the resources used by the recipes felt boring, thus, all cards were designed to have two effects, one that is applied instantly when the card is played, and another that is continuous and its applied constantly once the card is in the board. The progression resource is partially shared, since all recipes use all resources except one, at any given point each player shares two resources that need to be collected, and one that is exclusive to each player. Figuring which one is which is meant to drive gameplay and will create situations of cooperation and conflict throughout the game.

The visual design of the cards in this first iteration is very basic in order to prototype fast and does not aim to represent the final aspect of the game, and after the first playtesting sessions it became apparent the need of bigger icons as well as colour coding the different resources produced by the cards. An example of the design of the cards in this first iteration can be seen in figure 24.

**Figure 24**

*1st Iteration of cards*




Note. The first version of the card's visual design. Own work.

During this first implementation of the cards, they were all simple enough to be created using only icons. This was initially done to prototype faster, with more elaborate descriptions and rules prepared to be written in the future, when the core mechanics and rules of the game would be more consolidated, but playtesting showed that the cards were understood clearly without text so the icons stayed in future redesigns. They synergized well with the apparent simplicity of the game, and helped in identifying quickly what would produce each card. Some of the most complex mechanics of the game required more abstract icons, but play testers were not confused by them and they were well received.

### 2nd Iteration

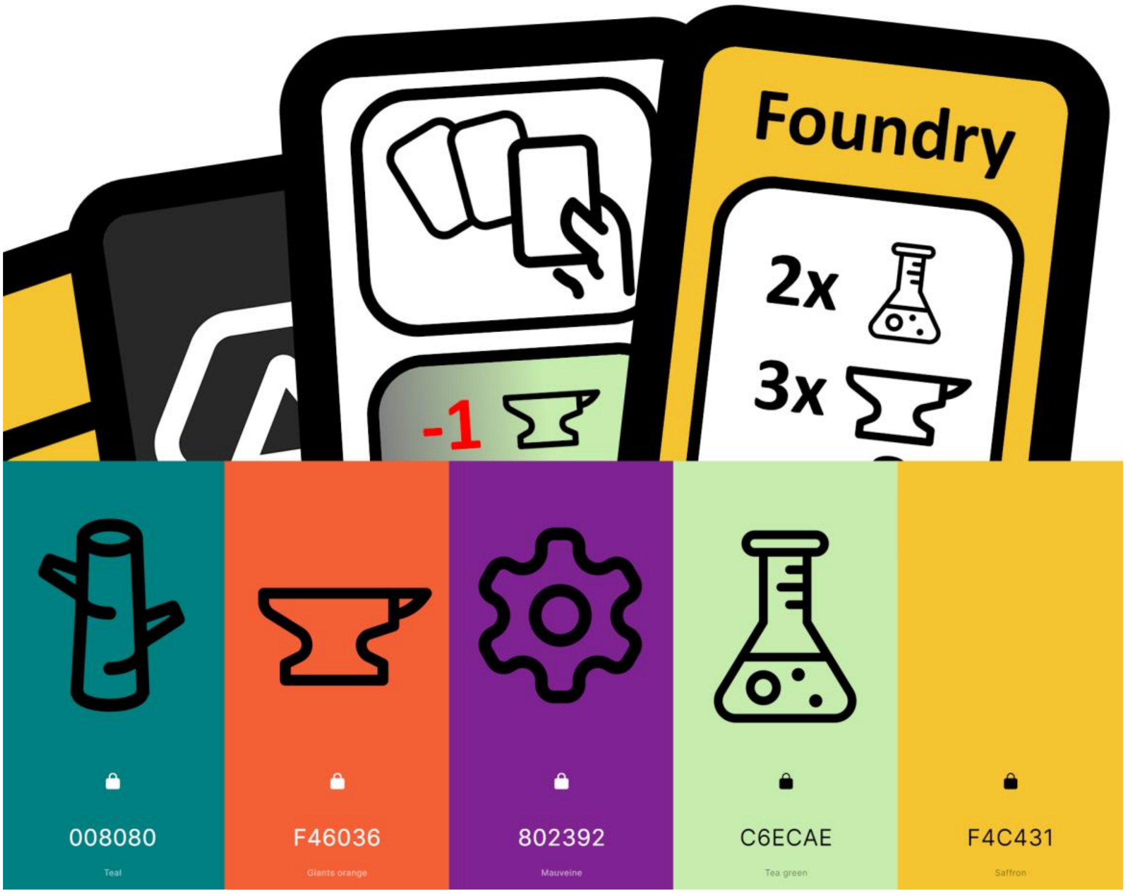
After testing the first iteration with a few play testers experts in card games, their feedback was gathered and changes were implemented accordingly. There were too many cards that exchanged cards from one player to another, so they were reduced since they were tedious and very disruptive when too many were played consecutively. There were cards that countered an opponent’s effect that generated interesting dynamics, but they were too different from the rest of the cards in the game to feel cohesive, and a very similar effect could be achieved by removing the effects of the last card played. Reaching the end of the deck was something that happened every game due to low generosity and players quickly discovering their opponent's recipes and preventing their completion, but that did not lead to an uninteresting game state, only a late-game state with higher stakes and instead of a focus in generating resources, the focus of the players is to minimise the resources their opponents need. Still, the games dragged for too long and not only the generosity has been increased to prevent this, the cost of the recipes have been reduced from 4,4,2 resources to 4,3,2 resources, making them cheaper and also generating more focus in specific resources and incentivising risk/reward strategies by incentivising to accumulate some resources more than others. The number of cards that allowed to see and order the top of the deck has been increased since it was an effect considered interesting by play testers that allowed to filter what your opponent and you would draw in the next turns that also allowed mind games and counterplay by playing another in response, changing the order back and gaining information of what your opponent prioritises in the process.

The biggest change in this iteration has been the change from one single stack of cards where all the resources are produced to one stack of cards for each resource, making the game much more visually clear, allowing players to quickly identify how many resources of each type are present in the board at any given time. This change has made the “remove last card from the pile” effect change into a resource-specific removal effect that allows players to take the last card that produces a specific resource, and generate another in the process.

The visual design of the cards has also been updated, with bigger icons and colour coding the resources so they can be quickly recognized from the board, as shown in figure 25.

**Figure 25**

*2nd Iteration of cards*




Note. A colour palette has been defined to easily distinguish the resources. Own work.

The first draft of the game’s rulebook was also developed during this iteration, and play testers played the game without any guidance, only the rulebook. They understood the game well and were able to play without much confusion.

### 3rd Iteration

During the previous iteration playtesting was increased, with more players with very different levels of experience when playing card games. These sessions confirmed that most of the initial assumptions of the game were correct (risk/reward mechanics when obtaining resources, the escalation of tension as the game goes on, etc). The overall reception of the game was very positive, but there was plenty of room for improvement and polish, which was implemented in this version.

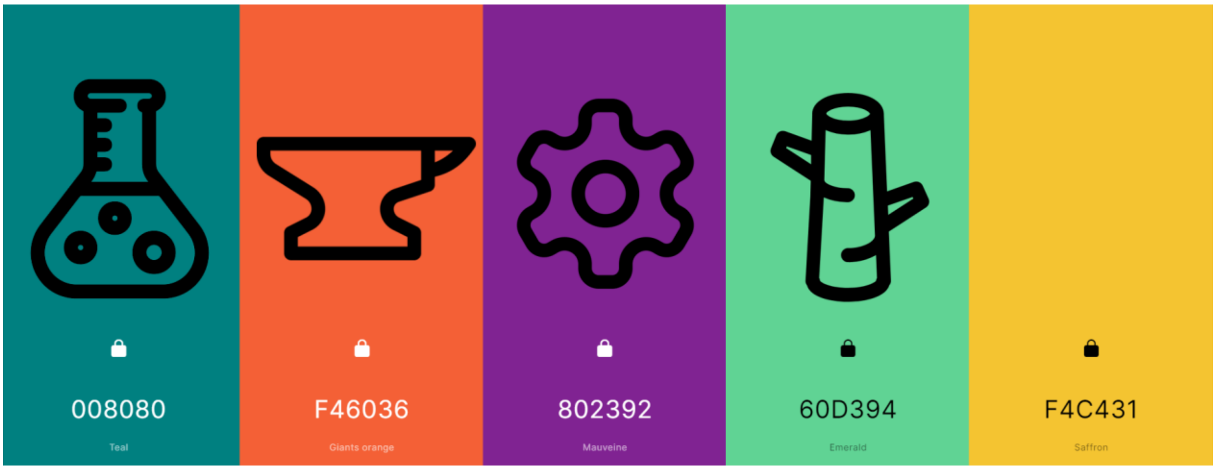
The cards contain two effects, one is the immediate effect they produce when played, and the other is the continuous effect they produce once they are on the board. The cards that removed one resource and added another had this effect written in the continuous category, but the removal part was immediate, so they were labelled properly. More diversity of effects was included, and the amount of deck manipulation effects was decreased, as players felt they were too frequent. The hand size limit was updated, as playtesting showed that 4 initial cards and 6 maximum cards in hand performed well with the control group. Still, some card draw reductions were needed. Reaching the end of the deck was quite prevalent, and a shuffle back of the discarded cards was mandatory to prevent the game from being unfinishable in some edge cases. The change to the cards that allowed players to look at the top card of the deck to look at the top three cards of the deck has been very well received, even if players thought that it appeared too often. The concept of cards that only have continuous effects or one-time effects is interesting and was implemented in this iteration. Recipe cost has been updated to swap the resources in the 3 and 4 costs, this change maintains the uneven resource focus that allowed strategy and risk-reward plays, and does not alter the total cost of recipes, but results in more even match-ups making the game less luck-based. Generosity was also increased by changing all cards that removed one resource and added another into cards that removed one resource and added two of another. Overall, simple cards worked well with play testers as they felt that even if cards do not have very complex effects by themselves, the long-term strategy was interesting and allowed them to build up resources in engaging ways.

Play testers suggested many changes to the game specific to two player mode or four player mode. They felt that the game was very different from one mode to another, even if in both cases they indicated that it was enjoyable. This led to many considerations to include or exclude effects depending on the number of players, but ultimately it was decided that the game would be kept the same regardless of the number of players, as this would lead to less confusion and the fact that games felt different was not considered a bad thing, just different experiences that were all enjoyable.

Most of the visual redesign of the game was done in the second iteration, but some changes were made in this iteration too. A new colour palette was developed as well as changing some of the icons to increase visual consistency, as shown in figure 26. The cards that removed one resource and added another previously had a gradient colour to differentiate them, but since the removal and the addition effects were now divided in the two sections of the card, all gradients were removed from the game.

**Figure 26**

*3rd Iteration colour palette*




Note. The chemical and wood colours have been updated, and the chemical icon now has the same width as the rest of the icons. Own work.

### 4th Iteration

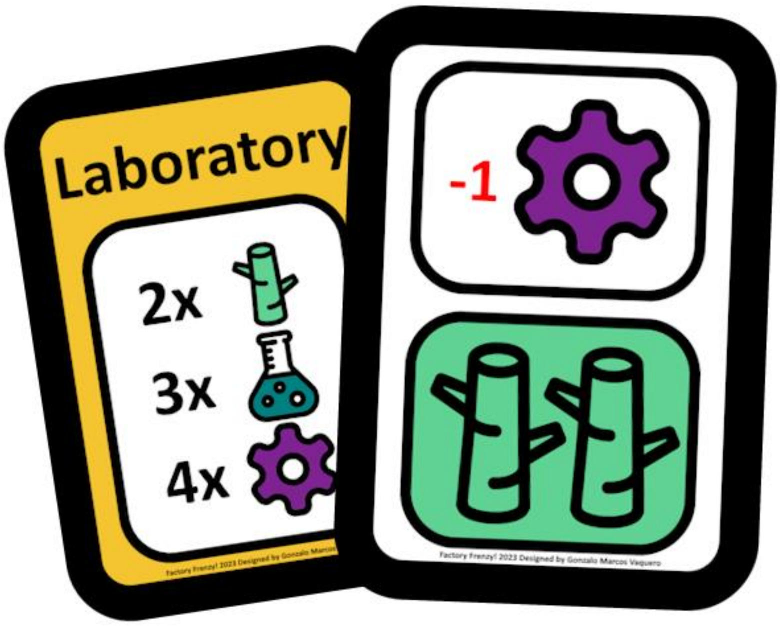
As the iterations continue, the number of changes decreases the more polished the demo gets. In this fourth iteration, the number of changes is low but their impact is significant.

The reveal recipe effect had mixed opinions on play testers. Some enjoyed the information it gave them while others disliked it greatly, feeling that it had a low impact on the game and most of the time they would prefer to have other cards instead. That effect has been replaced with swapping two player's recipes. The objective of this effect is to increase tactical options while still preserving information trade-offs and a focus on strategy. Generosity was increased in previous iteration and games felt too fast, sometimes without the chance to stop opponents from amassing too many resources. A universal removal card has been implemented to help deal with the feeling of inevitability in the later stages of the game by allowing to remove one resource card of any kind. Deck manipulation effects seems to be reduced to a more preferable amount and for now will be kept the same as the previous iteration. Players liked those effects from the first iterations but their amount felt too high, but it seems that in this iteration there is just the necessary amount. The cards with only immediate effect and no continuous effect were well received, but there is only one kind of them (draw two cards, remove one resource), which does not feel very cohesive since there is not a great variety of effects related to them. Still, they greatly improved the gameplay options and felt refreshing for play testers, so they will be maintained for this iteration. The names of two recipes have been swapped since the cost requirements are more thematic this way (Laboratory requires four chemicals now), but their numerical values have remained unchanged, preserving the balance in recipe costs. This change is very minimal and does not have any mechanical implications in the game.

There has been a change in the visual design of the game, modifying the recipes and cards that remove resources with colour coded icons so they are more visually clear in their effects, as shown in figure 27. In its current state, the game has a pragmatic design intended to make the game as readable and clear as possible. This does not mean that the game is designed with the objective of being visually unappealing, but the priority when designing icons, colour palettes, and card layouts has been pragmatism and not aesthetics.

**Figure 27**

*4th Iteration of cards*




Note. The icons of the resources have been coloured to increase visual clarity. Own work.

# Conclusions

This thesis has successfully achieved its objectives of analysing, categorising and implementing resource management systems in card games. Through a comprehensive analysis of the current theories and their implementations in some of the referent games on the market, valuable insights have been gained into how these elements shape the gameplay experience. The findings from this analysis have been distilled into a set of guidelines for designing resource systems, providing game designers with a framework to create engaging, balanced and cohesive resource management systems. These guidelines have been put into practice in the practical implementation of a card game, serving as a testbed to validate their effectiveness.

By accomplishing these objectives, this thesis aims to make a significant contribution to the understanding and development of resource management systems, in card games or otherwise. The analysis, guidelines and the practical implementation of the prototype collectively provide valuable insights and tools for game designers, empowering them to create more nuanced, complex and balanced resource systems in their games.

It is hoped that the knowledge and recommendations presented in this thesis will inspire further research and innovation in the field of resource management systems. Thanks to these advancements, the gaming industry can continue to push the boundaries of player engagement and create captivating experiences for players worldwide.

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# Card Design Iterations Spreadsheet

Card design iterations, numerical values and design notes. Please refer to the excel file provided named **Card Design.xlsx** and can also be found here:

https://docs.google.com/spreadsheets/d/1-nQS4oENufAkrzOZebhbL9-EO0BgAbQzcyh1QcL-u98/edit?usp=sharing

# Factory Frenzy! Rulebook

Welcome to Factory Frenzy! A card game developed by Gonzalo Marcos Vaquero for his bachelor's thesis at the university TecnoCampus Mataró-Maresme. Factory Frenzy! is a turn-based card game for two to four players about collectively managing resources in order to build a secret recipe.

## Initial setup

The game has two decks: the **recipe deck** and the **main deck**. Before starting, reveal the recipe deck to all players and then shuffle it. Each player receives a secret **recipe** card. Shuffle the **main deck** and deal four cards to each player. The first player is chosen randomly and turns are played in clockwise order.

If a player is not pleased with their starting hand, they can choose to shuffle back the cards and draw back four new cards. This process can only be done once per player.

## Turn Overview

Every player's turn consists of the following steps:

1. Check if the player can **win the game**.
2. The player draws a card from the **main deck**.
3. The player **plays a card**. If no card can be played, skip this step.
4. The player can **reveal** their recipe if they so desire.
5. The player discards cards until they have six remaining in their hand. The recipe does not count towards this limit.

More information about each of these steps is provided in their specific sections of the rulebook.

If at any point a player has to draw a card, and no more cards are remaining in the **main deck**, the **discard pile** is shuffled back into the **main deck** and then the cards are drawn.

When a turn is ended, the next player in clockwise order starts their turn. This is repeated until a player **wins the game**.

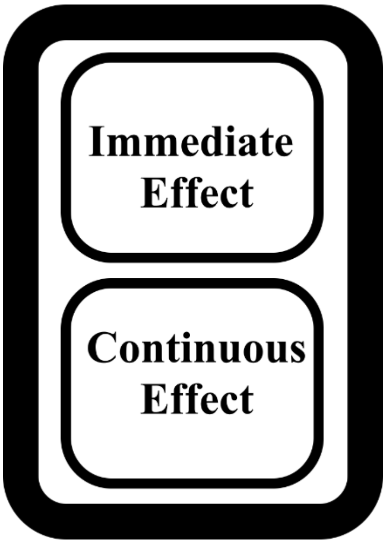
## Playing cards

Only one card can be played per turn, and all cards consist of two parts, the **immediate effects** at the top and the **continuous effects** at the bottom, as shown in the figure 28.

When a card is played, their **immediate effects** are applied. Then, if the card contains continuous effects, it is placed on the **board** and the **continuous effect** is applied from that point onwards. If the card does not contain continuous effects, it is placed in the **discard pile**.

**Figure 28: Card effects scheme**

*Card effects scheme*




Note. The top element of the card indicates its immediate effects, and the bottom element indicates its continuous effect. Own work.

Information of each one of the different Immediate and Continuous effects can be found in the **Card effects** section of the rulebook.

## Board Overview

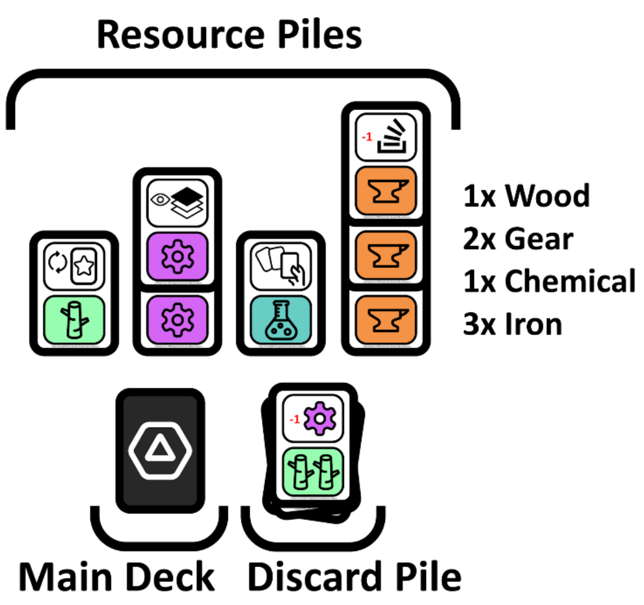
When a card with continuous effects is **played**, they are placed on the **board**, which is organised into the following elements:

- **Main deck:** Contains the cards of the game.
- **Discard pile:** Contains cards that have been discarded or removed from the board.
- **Resource piles:** Cards that have been played and are grouped according to the resource they produce. The cards in the piles are organised as a stack and new cards are put at the top of the pile. The resources present in the game are Chemicals, Wood, Gears and Steel.

The **board** is public and affects all players. When a resource is added to the **board**, all players can benefit from it in order to complete their **recipes**. As shown in figure 29, there is a total of 1 Wood, 2 Gears, 1 Chemical and 3 Irons present on the board.

**Figure 29: Board example**

*Board example*




Note. Example of a possible board state and the resources it contains. Own work.

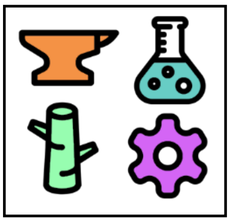
## Winning the game

The process of winning the game consists of two parts, declaring that you are going to build the secret **recipe** and completing the **recipe**.

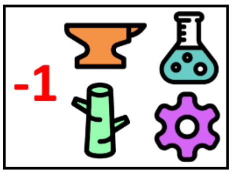
During a player's turn, they can declare that they are going to build the **recipe** if enough resources to complete it are present on the **board**. When this is done, the **recipe** has to be revealed, visible for all players.

When a player starts their turn, if they have previously declared that they can build the **recipe** and the required resources are present on the **board**, they **win the game**.

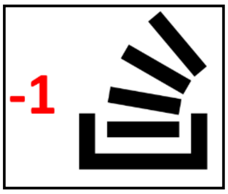
## Card effects



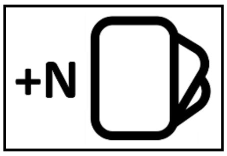
For each symbol, add one resource of the specified type to the shared resource pool among all players.



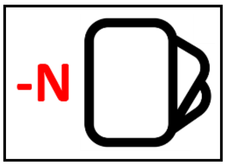

Remove the top card of the specified **resource pile** and place it in the **discard pile**. This effect cannot be played if no card would be removed.



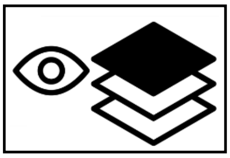

Remove the top card from any **resource pile** and place it in the **discard pile**. This effect cannot be played if no card would be removed.



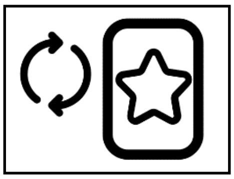

Draw N cards from the **main deck**.



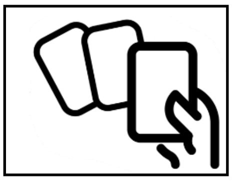

Discard N cards into the **discard pile**.



Look at the top three cards of the **main deck** and return them in any order.



Target player and you exchange your **recipes**. The recipes are returned to each player's hand and are no longer revealed nor declared for completion.



Take a random card from a player's hand. **Recipe** cards cannot be stolen.

# Factory Frenzy! The Card Game

In order to play the card game, you have to print and cut the cards in this document: Factory Frenzy! Complete Cards.pdf and can also be found here:

https://drive.google.com/file/d/1R0-d6b5KXjfIBret4-lAFUgRRP8zM78J/view?usp=sharing

The version with the back of the cards included and without cutting lines can be found here: [Backs included] Factory Frenzy! Complete Cards.pdf and can also be found here:

https://drive.google.com/file/d/1VW3E0xUXd_IZzd5KVAf8kk4agDHZvR8L/view?usp=sharing

The rulebook can be found in the file Factory Frenzy! Rulebook.pdf and can also be found here:

https://drive.google.com/file/d/1nIDMLTct8m2_fhqRvjyhwAAsoAl7jhbJ/view?usp=sharing

Once the cards are printed, cut them according to the cutting lines and put the white-background cards together forming the main deck and the yellow-background cards together forming the recipe deck.

The card that contains the QR code of the rulebook is not part of the main deck and its purpose is to provide access to the rulebook.

# Playtesting survey and responses

The questions and answers in the playtesting survey can be found in the **Playtesting Survey (Responses).xlsx** and can also be found here:

https://docs.google.com/spreadsheets/d/1yKbUhEwvGUA6BzJVaHJl47wPc5fqwQmrSSgF0wUM6_k/edit?usp=sharing

# Figures and diagrams

All the figures and diagrams present in the thesis are own work and can be found here:

https://drive.google.com/file/d/18AWPh3v61Y2VG4C9KaTt2BA8LVnjPpyb/view?usp=sharing

# Literature research

In order to find references of quality and relevance, a study of authors and thesis has been done in order to properly develop the theoretical aspects of this thesis. The spreadsheet with the literature research can be found in the **Literature.xlsx** file and can also be found here:

https://docs.google.com/spreadsheets/d/1ucmoPnGuBHxAWRD3P1jpKiu3ZQqIG6PcJTYSr81Wn7o/edit?usp=sharing