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RESEARCH TOPIC

Predicting Dominant Designs: A Multi-Criteria Approach to Innovation Strategy

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Abstract

This thesis explores the emergence of dominant designs in technology-intensive industries through a comparative, multi-case approach. Building on the limitations of traditional models such as the Abernathy-Utterback and Suarez frameworks, it introduces the Dominant Design Prediction Matrix (DDPM), a simplified yet multidimensional tool designed to support early-stage technology assessment. By evaluating five key dimensions, Technological Superiority, Complementary Assets, Economic Feasibility, Regulatory & Policy Influence, and Customer Preferences, the DDPM provides a structured method to compare competing technologies. The model is applied across diverse case studies, from data centers to EV charging and additive manufacturing, to identify common patterns and assess the strategic alignment that leads to dominant design emergence. While not predictive in a deterministic sense, the framework helps clarify trade-offs, support scenario planning, and improve strategic foresight. The final outcome offers a pragmatic and adaptable tool to aid innovators, investors, and policymakers in navigating uncertain technological landscapes.

CHAPTER 1 - Introduction

Technological innovation has always been at the forefront of industrial transformation, dictating the competitive forces of entire industries. With advancing technologies, markets will go through periods of uncertainty where there are multiple competing solutions with varying benefits and tradeoffs. Eventually, however, one particular solution starts to become the industry standard a phenomenon well documented as the emergence of a dominant design.

It is crucial that companies, policymakers, and researchers comprehend why and how dominant designs take place. Companies undergoing technological change need to be able to predict which designs are likely to dominate in order to allow them to make rational investment choices, and policymakers require an imperative to coordinate policy to allow effective and sustainable technological development. Dominant design, a concept first introduced by Abernathy and Utterback, is one such theoretical framework through which this process can be understood. It suggests that industries go through an initial phase of fluid competition, with various technological alternatives competing, before settling down to a standard which locks in the future path of the industry. However, while the theory explains the phenomenon, it remains a big issue to foresee which technology is most likely to emerge as dominant.

The motivation for this research is in the need to construct a systematic method of examining and forecasting dominant designs in industries. As opposed to firm level studies of dominant design emergence, the present research is industry centered with recognition that technological dominance is most frequently induced by forces that are more systemically oriented. A comparative case study approach is employed to construct patterns and commonalities of dominant design emergence across different industries.

In order to respond to these questions, the research employs a multiphase research method through the use of quantitative and qualitative techniques. A case study of six industries, where each industry is an industry through which technological leadership is being formed, is conducted initially. These matters form the analytical platform from which it can be determined which designs are more than likely to prevail. These technologies are subsequently given a semiquantitative score, taken on a mixture of performance indicators, costs, and customer take up, in order to provide each technology with a better prediction of how well it will perform in the future.

This research is intended to provide a progressive treatment of the topic. The next chapter is a literature review of common design theories, technology forecasting methods, and CFTP as a planning tool. This is followed by the methodology chapter that outlines the analytical framework and data sources used. Most of the thesis consist of six case study chapters, one for each industry where rival technologies are vying for market share. Finally, the conclusion and synthesis make connections between industries, seeing common trends and constraining the forecasting model developed in this research.

By drawing together knowledge from a range of industries, the research aims to contribute to an understanding of the forces driving technological transformation and market convergence. The ability to anticipate dominant designs is not only of academic curiosity but has practical relevance to companies and policymakers struggling to navigate the uncertainties of technological competition. Lastly, the result of this study is expected to provide a systematic approach to evaluating and predicting what technologies will influence the future of their intended industries.

CHAPTER 2 – Literature review

2.1 - Definition of dominant design

The idea of "dominant design" emerged from pioneering studies on industrial innovation in the 1970s. One of the foundational works introducing this concept, "A Dynamic Model of Process and Product Innovation", was developed by theorists William J. Abernathy and James M. Utterback. Their model has since become a cornerstone of innovation management theory. They collaborated to create two conceptual frameworks that explained the effects of innovation in a generic industrial sector: one focused on the competitive strategy of a firm, while the other addressed the characteristics of the production process, distinct but highly complementary concepts. They proposed that the innovation process systematically varies based on the stage of development of the company's production process, the technological state of the product, and the firm's overall strategy aimed at competition and growth (*Abernathy & Utterback, 1978*). This framework introduced a structured understanding of how industries evolve and how the development of a dominant design is influenced by various internal and external factors.

Once a dominant design emerges, it not only consolidates the current market but also shapes future generations of products within that particular category. This creates what *Schilling (1998)* refers to as an architectural franchise, where the firm that developed the dominant design reaps significant competitive advantages. By setting the standard, the dominant design often pushes competitors out of the market, as rivals struggle to match the economies of scale and efficiency achieved by the company with the dominant design. This dynamic leads to increased market consolidation, where fewer companies can effectively compete unless they adopt the dominant design or innovate beyond it.

The introduction of the dominant design concept marked a monumental shift in the study of innovation dynamics. Before Abernathy and Utterback's contributions, much of the research on innovation was primarily descriptive, focusing on identifying innovation trends and variations in different industries. However, these early studies often lacked a robust theoretical framework to explain the underlying causes of these trends. Abernathy and Utterback's work provided a much needed conceptual structure that clarified why certain designs gained dominance, why others faded away, and how technology and market forces interact during the innovation process (*Utterback, 1994*).

2.1.1 - The Abernathy and Utterback model:

At the heart of their model lies the idea that as a company's production process matures, it progresses toward higher productivity. This evolution is driven by several factors, including increased capital intensity, improved specialization of tasks, and a more efficient division of labor. Over time, product design becomes more standardized, leading to greater consistency and cost effectiveness in manufacturing. The flow of materials within the production system also becomes more streamlined, further enhancing productivity and reducing waste *(Abernathy & Utterback, 1975*).

The central premise of Abernathy and Utterback's model is that production processes evolve in a predictable and recognizable way over time. This predictable trajectory is crucial for firms to anticipate and prepare for changes in their industry, aligning their strategies accordingly. As the innovation process unfolds, firms that are able to adapt to these shifts, whether through process innovation, strategic investments in new technologies, or by leveraging economies of scale, are more likely to emerge as leaders in their respective industries (*Abernathy & Utterback, 1978*).

They also defined three stages of development, which can be observed similarly across different sectors analyzed, and can be identified based on the characteristics of the production factors:

1. **Fluid phase:**

In the fluid phase, both the product and the production process are highly dynamic, experiencing rapid change and development. This phase is characterized by high levels of uncertainty, both in terms of technology and market preferences, as companies experiment with different designs and production methods. There is typically a broad variety of competing products and solutions at this stage, with no clear industry standard yet established. The diversity among competitors results in significant variation in product designs, features, and manufacturing techniques. Companies tend to focus on innovation and customization to differentiate themselves from competitors, leading to a production process that is highly flexible but also inefficient. During this phase, production is often manual or semiautomated, with operations being non standardized. While this flexibility allows companies to rapidly adapt to market changes, it also means that economies of scale are not yet achievable, and production costs remain high. Companies are still learning about what will work best in the market, and as a result, the system is highly fluid and lacks stability.

2. **Transitional phase:**

As the market begins to mature, the transitional phase represents a shift from flexibility to efficiency. In this phase, the dominant design starts to emerge, as consumers and companies begin to converge on a preferred set of features or product architecture. The product stabilizes and becomes more standardized, while competition moves away from product variety and towards price. Companies start to prioritize cost reduction and operational efficiency, leading to the adoption of automated processes and specialized equipment. Although some aspects of production remain manual, automation is increasingly integrated into certain subprocesses, allowing for improved efficiency and quality control. At this stage, companies also begin to establish formal routines and organizational processes, further enhancing the efficiency of production. The production system becomes more predictable, with clear divisions of labor and roles within the company. This segmentation in the production process results in a blend of manual and automated tasks, where specific tasks may require human input while others are highly optimized through technology. The focus during this phase is on refining the production process and reducing variability to meet growing demand and compete on price. The integration of automation helps to reduce labor costs and improve consistency, but the process remains in transition, with some parts still lacking full optimization.

3. **Specific phase:**

In the specific phase, the production process has reached a point of near total optimization, where the focus is on fine tuning and maximizing efficiency. By this stage, the dominant design is fully established, and companies invest heavily in production infrastructure to maximize output and minimize costs. The system becomes highly specialized and integrated, with automated machinery performing most of the production tasks. Labor is minimal and mostly focused on supervising and maintaining the equipment rather than performing manual tasks. The production process is so efficient that further improvements become increasingly difficult and costly. Because of the high level of integration, even small changes to the process or the product design can result in significant disruptions and expenses. The production system is highly rigid at this stage, and companies are focused on maintaining consistency and maximizing economies of scale to remain competitive. This phase typically represents the end of radical innovation in the production process, as improvements are now incremental and focused on maintaining efficiency rather than introducing new technologies or methods. Companies in this phase benefit from low production costs and high output, but they also face significant challenges in adapting to new market conditions or technological changes due to the rigidity of their processes.

In each of the three phases, the focus is the maximization of three different aspects, in the first phase the Performance, in the second the sales and in the last the Cost. Below it will be explained in details of each of the three processes:

1. **Performance maximization:**

This phase is marked by the introduction of groundbreaking products that emphasize technological innovation and unique features. At this early stage, companies prioritize creating highly differentiated products that push the boundaries of performance. The key goal is to maximize the product's capabilities to stand out in a market that is still undefined and fragmented. Companies entering this phase are often pioneers or early entrants, typically smaller firms or innovative startups. These firms rely heavily on technological expertise to introduce novel solutions that address unmet needs in the market.

During this phase, product designs vary widely, and firms are not yet focused on standardization. Instead, they are experimenting with different approaches, and the production process remains in its infancy. Customization is key at this stage, as each company tries to carve out a niche. The production process itself is often manual, labour intensive, and non-standardized, making it inefficient but highly flexible. The market is full of uncertainty, as customer preferences are not yet clearly defined, and firms must continuously adapt to emerging trends and technological developments. Innovation here is usually inspired by new market opportunities rather than radical scientific advancements, which means firms must be closely attuned to changing customer needs.

Because the focus is on performance enhancement, companies in this phase invest heavily in research and development (R&D) to refine their technologies. However, the production scale is often limited due to the high costs and lack of standardized processes. Companies are also likely to be working on securing intellectual property (IP) protections, such as patents, to defend their unique innovations from competitors. The result is a phase marked by technical uncertainty, where only a few firms may succeed in commercializing their innovations and setting the stage for future market dominance.

2. **Sales maximization**

As the market evolves, companies shift their focus to sales maximization, where the aim is to expand market share by appealing to a broader customer base. By this point, product designs have stabilized, and the industry has started to coalesce around certain dominant design features. The competition moves away from purely technological innovation toward product differentiation, as companies strive to distinguish their products in terms of features, branding, and customer service. At this stage, manufacturers and consumers alike have gained a better understanding of the product, reducing market uncertainty.

In response to increasing demand, companies begin to optimize their production processes. Automation is introduced in areas where possible, but some processes may still be manual, resulting in a mix of automated and manual operations. Companies may also invest in supply chain optimization and logistics to scale up production efficiently. Marketing and sales strategies become crucial as companies attempt to capture larger segments of the market through advertising, promotions, and pricing strategies. The introduction of new models, components, or complementary products often takes place during this phase, allowing for further differentiation.

The focus in this phase is on growing sales volumes, which may lead companies to adopt strategies like lower pricing, bundling, or offering value-added services to attract a larger customer base. As competition intensifies, price sensitivity becomes a key factor, and companies must balance product variety with cost control. Firms that can manage to scale production while keeping costs low without sacrificing product quality or differentiation are the ones that thrive. Companies may also begin international expansion, adapting their products to different markets and regulatory environments to maximize sales.

This phase is also characterized by process innovation. As demand increases, companies seek ways to improve production efficiency. This often leads to organizational changes or new business structures designed to support increased production capacity. Companies may also begin to explore strategic partnerships or alliances to access new markets or technologies, further driving their growth and market penetration.

3. **Cost minimization**

In the final phase, companies focus on cost minimization, where the product life cycle has reached maturity, and market dynamics shift towards standardization and efficiency. The industry consolidates around dominant designs, and the competition is largely based on price. At this stage, there is little variation in product features, and most innovations are incremental improvements focused on reducing costs or optimizing performance. Firms that succeed in this phase are those that can leverage economies of scale to reduce production costs and offer competitive pricing.

The production process in this phase is highly automated and capital-intensive, with significant investments made in infrastructure and technology to achieve maximum efficiency. Firms prioritize streamlining operations, reducing waste, and optimizing the use of resources. Lean manufacturing techniques may be employed, and firms may invest in new manufacturing technologies to further cut costs and improve output.

The focus in this phase is also on supply chain efficiency and logistics management. Companies seek to reduce input costs by negotiating better terms with suppliers or finding alternative materials. Process optimization becomes critical, with any inefficiencies identified and corrected to minimize production downtime and improve throughput. As competition drives down profit margins, firms need to be cost leaders in the industry to survive. Many firms in this phase operate in an oligopoly, where a few large players dominate the market, and price wars are common.

With standardization in place, companies also aim to lock in customers through after-sales services, extended warranties, or product upgrades. However, the rigidity of the production process at this stage means that any changes to the product design or process can be costly and disruptive, so companies must weigh the trade-offs between innovation and cost efficiency carefully. Most innovation happens at the level of suppliers or component manufacturers, where incremental improvements can lead to further reductions in cost for the primary producers.

At this stage, the primary goal is to maintain market share and continue driving down costs while keeping a close eye on emerging trends or disruptive technologies that could pose a threat to the established dominant designs.

2.1.2 - Limitation of the model

Initially, various aspects of innovation in its different forms were not considered, as the model only refers to the manufacturing industry producing assembled products, thus excluding process or service industries. The evolution of technology and the economic system inevitably makes this model debatable from several perspectives, as it does not consider certain variables that cannot be overlooked in the present and future.

In the early stages of market development, technical uncertainty and the vast market lead to a wide range of product designs (Abernathy and Utterback, 1978). However, history demonstrates that the dominant design isn't necessarily the one with the highest technical performance. Instead, it is the design that optimizes technological potential by aligning the interests of suppliers, users, and competitors.

Several key aspects limit the model's applicability and generalizability across different industries and technological landscapes:

Focus on manufacturing industries: One of the primary limitations of the Abernathy-Utterback model is its focus on manufacturing and assembly industries. The model was developed based on research in industries that produce physical products, such as automobiles and machinery, where production processes and product designs evolve in tandem. As a result, it is less applicable to industries where the production process is service oriented or highly digital, such as software development, finance, or healthcare services. In these sectors, the fluidity of innovation and the absence of tangible production processes mean that the stages of innovation described in the model do not always apply or evolve in the same predictable way.

Overemphasis on standardization: The model assumes that industries inevitably progress toward a dominant design that leads to standardization and cost minimization. While this may be true for many traditional manufacturing sectors, it overlooks industries where continuous innovation and differentiation are essential to maintaining competitive advantage. For instance, in fast evolving technology sectors innovation doesn’t follow standard phases (fluid, transitional and specific), the pace of change is too fast, for this reason, companies may deliberately avoid standardization to retain flexibility and the ability to innovate. These industries often face rapid technological obsolescence, making the emphasis on standardization and cost efficiency less relevant in practice.

Limited consideration of disruptive innovation: Abernathy and Utterback’s model does not fully account for the impact of disruptive innovations, which can radically change an industry’s trajectory. Disruptive innovations, as described by Clayton Christensen, can create entirely new markets or significantly reshape existing ones, often bypassing the dominant designs that have already emerged. The Abernathy-Utterback model assumes that once a dominant design is established, the focus shifts to incremental process improvements, but in reality, disruptive technologies can emerge at any time, resetting the competitive landscape and rendering the dominant design obsolete.

Underemphasis on external factors: Another limitation is that the model does not sufficiently address the role of external factors, such as regulatory changes, geopolitical events, and economic fluctuations, which can significantly influence the innovation process. For example, government policies, such as subsidies for clean energy or restrictions on certain technologies, can shape the direction of innovation, sometimes accelerating or stalling the emergence of a dominant design. Similarly, global supply chain disruptions, technological breakthroughs from adjacent industries, or shifts in consumer behavior can dramatically alter the expected progression of innovation.

Insufficient attention to customer driven innovation: The model emphasizes the role of firms in driving innovation through process and product development, but it gives limited attention to the increasing importance of customer driven innovation. In today's market, customer feedback, user data, and community driven development often play a significant role in shaping product evolution, particularly in sectors like software, consumer electronics, and fashion. The Abernathy-Utterback model's linear view of innovation overlooks the iterative feedback loops that are critical to modern innovation processes, especially in industries where customization and personalization are key drivers of competitive advantage. At the same time, the model is not structured to address modern customer needs; for example, it doesn't take into account sustainability factors, which are no longer negligible today.

These limitations suggest that while the Abernathy-Utterback model remains a valuable tool for understanding the dynamics of innovation in certain industries, it must be adapted and supplemented by other frameworks to account for the complexities of modern markets, technologies, and global challenges.

2.2. - Technology forecasting

Technology forecasting is a strategic tool used by organizations to anticipate future technological developments and trends. It involves predicting the direction, timing, and impact of technological innovations on markets, industries, and society. In the context of the fluid phase of the technological life cycle, where uncertainty and diversity of technological variants are high, technology forecasting plays a critical role in helping firms identify emerging technological paradigms. By providing insights into potential future developments, forecasting allows companies to make informed decisions about where to allocate resources, which technologies to pursue, and how to position themselves in rapidly evolving markets.

During the fluid phase, firms are faced with numerous technological options, and it can be difficult to determine which will become dominant. This is where technology forecasting comes into play, allowing companies to assess not only the technical feasibility of various technologies but also their market potential. Forecasting enables firms to evaluate emerging trends, customer needs, and market dynamics, offering a strategic advantage by helping firms focus on the most promising technologies that are likely to succeed in the future.

2.2.1 - Methods of technology forecasting

Several established methods of technology forecasting can be utilized during the fluid phase. These methods range from qualitative to quantitative approaches and vary in their scope and complexity. The following are some of the most commonly used techniques:

- Trend analysis:
  Trend analysis involves examining historical data and identifying patterns that can be extrapolated into the future. This approach is often used to project technological improvements in performance, cost, or adoption rates over time. For example, Moore's Law, which predicts the doubling of transistors on integrated circuits approximately every two years, is a classic example of trend analysis in the technology sector. While trend analysis provides a simple and effective way to forecast incremental improvements, its limitation is that it assumes past patterns will continue, which may not always be true in the case of disruptive innovations.

- Delphi method:
  The Delphi method is a structured, expert based forecasting approach where a group of experts is surveyed in multiple rounds. After each round, a summary of the opinions is shared with the participants, and they are asked to revise their views based on the feedback from others. This

process is repeated until a consensus is reached. The Delphi method is particularly useful for forecasting in highly uncertain environments, such as the fluid phase, where expert judgment is required to predict technological trends. Its strength lies in its ability to bring together diverse perspectives from technology experts, market analysts, and industry leaders to create a more robust forecast.

- Scenario planning:
  Scenario planning is a qualitative forecasting method that involves creating multiple, plausible future scenarios based on key uncertainties that could influence the development of a technology. In the context of the fluid phase, scenario planning helps companies explore how different combinations of factors such as regulatory changes, customer preferences, and technological breakthroughs, might shape the future of a technology. By considering a range of possible futures, companies can better prepare for various contingencies and strategically position themselves to capitalize on emerging trends.

- S-Curve analysis:
  S-Curve analysis involves mapping the performance improvement of a technology over time, identifying when it will move from the fluid phase of rapid development and experimentation to a more stable mature phase. The S-curve model helps companies estimate the point at which a technology is likely to hit its peak performance and when it will plateau, indicating the need for new innovations or alternative approaches. This method is particularly useful for assessing the lifespan of technologies and determining the best time to invest in or exit from a particular technology.

- Patent analysis:
  Patent analysis is a quantitative forecasting tool that examines trends in patent filings within a specific technology domain. A rise in patent activity can indicate the emergence of new technological areas or increased competition in an existing field. By tracking patent activity, companies can gain insights into which technologies are being actively developed, who the key players are, and where future innovations might emerge. Patent analysis helps firms identify potential technological breakthroughs and assess the competitive landscape during the fluid phase.

2.2.2 - Challenges of technology forecasting in the fluid phase

While technology forecasting offers significant benefits, it is not without challenges, particularly during the fluid phase of the technological life cycle. The fluid phase is marked by high uncertainty, and predicting which technological variant will ultimately become dominant can be difficult. Disruptive innovations, in particular, are hard to forecast because they often emerge from unexpected sources and may not follow existing trends. Furthermore, technological advancements do not always progress in a linear fashion, and external factors such as regulatory changes, economic shifts, or unforeseen breakthroughs can alter the course of technological development.

Another key challenge is the time horizon of forecasting. In the fluid phase, companies must balance short term decisions about which technologies to invest in with long term predictions about how the market will evolve. Making overly optimistic or conservative forecasts can result in missed opportunities or costly investments in technologies that fail to gain traction.

2.2.3 - Role of forecasting in identifying emerging paradigms

Despite these challenges, technology forecasting remains a vital tool for identifying emerging paradigms in the fluid phase. By systematically assessing potential technological pathways, firms can better anticipate which technological variants will align with market needs and become the foundation for future innovations. Accurate technology forecasting can provide firms with a competitive advantage, enabling them to lead the development of the dominant design or quickly adapt to it when it emerges.

Moreover, combining technology forecasting with other tools such as Customer Focused Technology Planning (CFTP) can enhance the accuracy of predictions by incorporating customer insights into the process. This integration allows firms to forecast not only the technical feasibility of a technology but also its market viability, ensuring that emerging paradigms are both technologically and commercially viable.

2.3 - Customer Focused Technology Planning (CFTP)

Customer Focused Technology Planning (CFTP) is a strategic approach that aligns technology development with the evolving needs and preferences of customers. In the fluid phase of the technological lifecycle, where there is significant uncertainty and experimentation, CFTP provides a critical tool for guiding firms toward technological designs that are most likely to succeed in the market. By prioritizing customer needs and expectations, companies can ensure that the technologies they invest in and develop are not only technically viable but also aligned with market demand.

At the core of CFTP is the principle that the customer should drive technological innovation. This is particularly important during the fluid phase, where numerous technological variants are competing, and it is unclear which will emerge as the dominant design. Companies that can accurately identify and respond to customer pain points, desires, and use case requirements are better positioned to influence which design becomes dominant. CFTP ensures that customer insights directly inform the design, development, and deployment of new technologies, making it a powerful tool for navigating uncertainty.

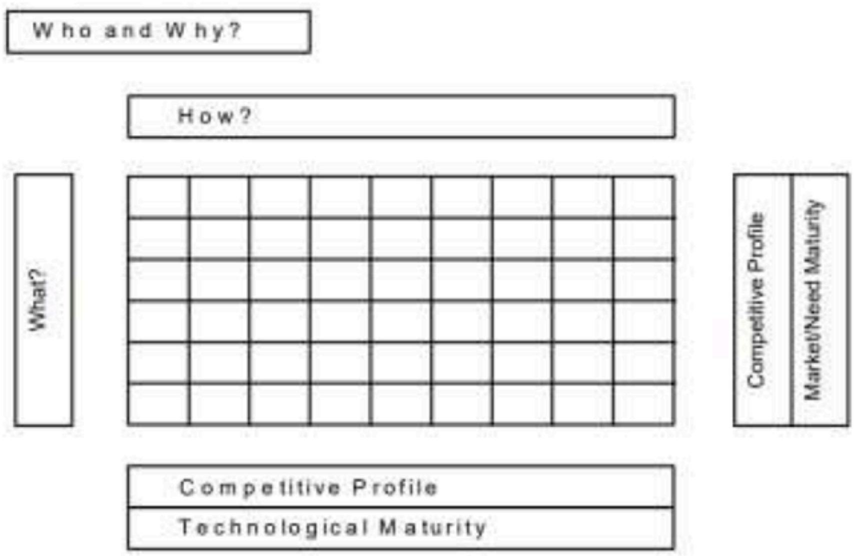


Figure 12. Generic CFTP map (Paap, 1996).

2.3.1 - Key elements of CFTP

CFTP consists of several key elements that help firms integrate customer feedback into their technology planning processes. The first element is customer centered research, which involves conducting surveys, focus groups, ethnographic studies, and gathering user feedback to capture both explicit and implicit needs. By focusing on real world use cases and pain points, companies can ensure that their technology development is relevant to the problems customers are trying to solve.

Market profile development

It answers the questions “Who are the customers and why are they important?”. It is equivalent to the top portion of the CFTP map. Product classifications are represented by rows, while market segmentation based on decision-making processes are represented by columns.

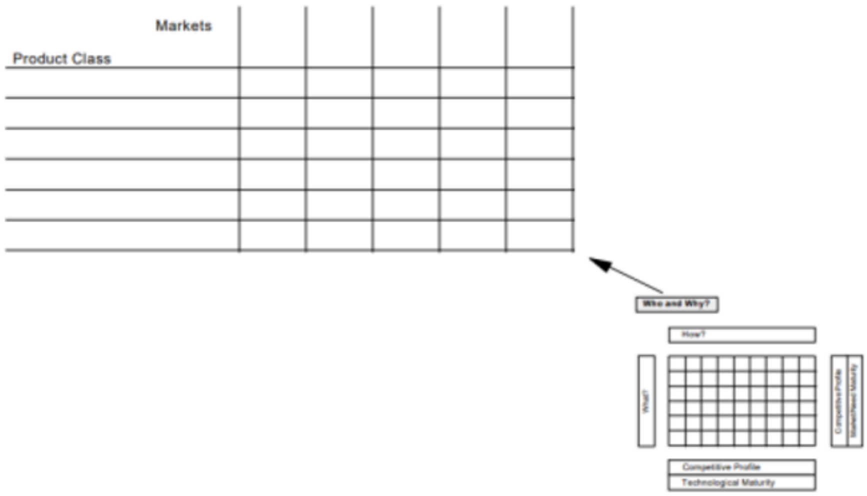


Figure 13. Generic CFTP product market map (Paap, 1996).

Technology market interactions map

Technical features, competitive dynamics, and market requirements are examined for every market category that has been identified. Customer decision-making elements and third-party influence factors are examined using the Performance Characteristics map.

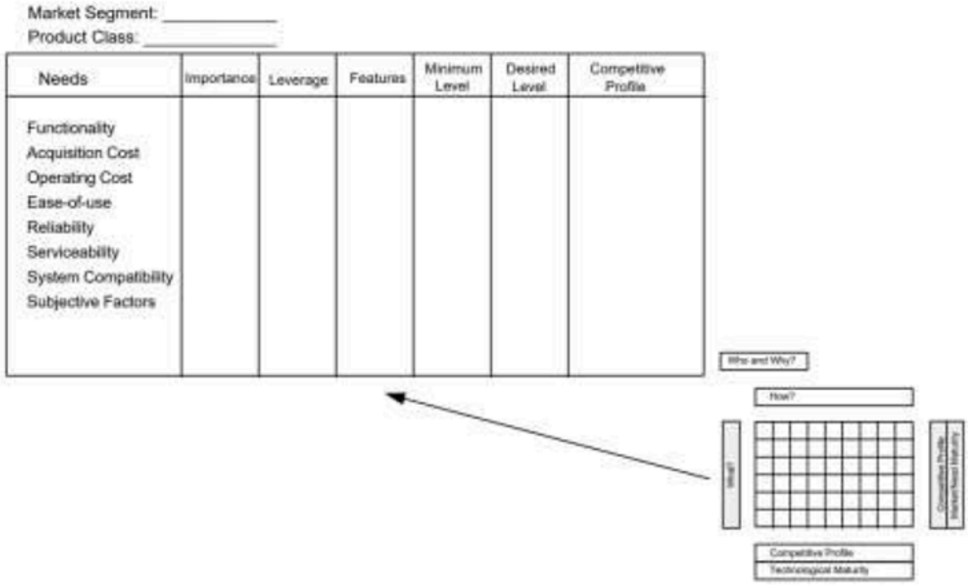


Figure 14. Generic Performance Characteristics Profile (Paap, 1996).

Technology investment opportunities identification.

Through a technology impact analysis some basic questions need to be answered: What performance characteristics drive the technology? When will the considered technology be mature? Where are we along the considered technology S-curve? Where is competition? What are the technical options and when will they be available to mass market?

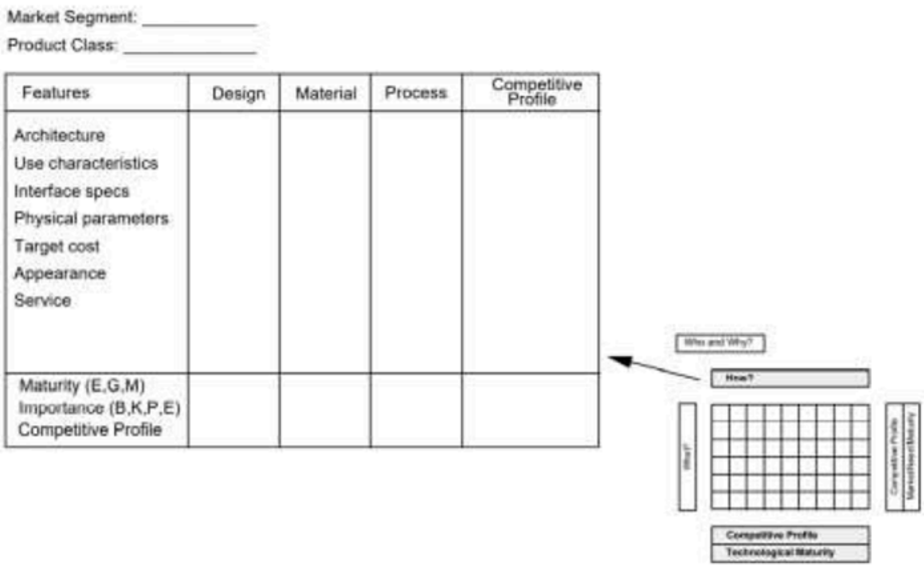


Figure 15. Generic Technology Impact Profile (Paap, 1996).

Projects and priorities selection

The CFTP map can be used to choose the direction of projects and investments after potential positive and negative interactions between performance criteria and technological effect have been examined.

Performance Characteristic	Importance	Leverage	Ingredient Technologies				Process Technologies		Competitors		
			Sweetners	Fats and substitutes	Shelf life enhancers	Flavorings	Formulation	Mixing	CI	A	B
Flavor	1	M	+	++	+	++	+	+	3	2	1
Appearance	2	L	+	+	++	o	++	+	3	2	1
Fat Content	3	H	o	++	o	o	o	o	2	1	2
Texture/ Mouthfeel	4	H	+	++	+	++	+	+	2	1	3
Price	5	M	o	+	+	+	++	++	3	2	1
Calories	6	L	++	+	o	o	o	o	1	1	1
	Competitor Profile	Constar Inc.	●	⊙	⊙	○	○	⊙	10% share		
		A	⊙	●	●	●	⊙	●	30% share		
		B	⊙	⊙	●	●	●	⊙	40% share		
	Relative Maturity		G	E	G	G	M	G			

Importance: Rank order, **1** is most important
Leverage: **H** = high **M** = medium **L** = low (refers to customer reaction to performance improvements)
Technology Impact: **++** = technology influences greatly (positive or negative) **+** = moderate impact **o** = low impact
Competitors: **1** = best **2** = second best **3** = third best; ties indicate equal performance
Competitive profile: ● = strong capability/high investment ⊙ = moderate capability/investment ○ = low capability/investment
Relative maturity: **E** = Emerging technology **G** = Growing technology **M** = Mature technology

Figure 16. Example of CFTP Map (Paap, 1996).

Another fundamental aspect of CFTP is alignment with value creation. Instead of merely meeting technical specifications or performance benchmarks, companies must understand what customers value most in a product or service. For instance, in the case of blockchain technology, customers in financial services may prioritize transparency and security, while customers in supply chain management may focus on traceability and speed. Ensuring that a technology aligns with the most critical customer value drivers significantly increases its chances of widespread adoption.

2.3.2 - CFTP in the fluid phase of the technological lifecycle

The fluid phase is characterized by technological diversity and uncertainty, with numerous competing designs, products, or technologies vying for market dominance. In this phase, customer preferences are not yet fully defined, making it difficult for companies to know which design will emerge as dominant. CFTP provides a systematic approach to reduce this uncertainty by placing customers at the center of the innovation process.

Adapting to shifting customer needs is one of the major benefits of CFTP. Customer preferences often evolve rapidly during the fluid phase as they become more familiar with emerging technologies. CFTP ensures that companies remain responsive to these shifts. For example, in the case of electric vehicles, early adopters may prioritize novelty and performance, but as the market matures, customer demand may shift toward affordability and infrastructure support. CFTP helps companies adapt their designs in real time, ensuring that they remain aligned with evolving customer priorities.

Preventing mismatched innovation is another key role of CFTP. One of the risks in the fluid phase is developing technologies that fail to resonate with customers, either because they are too advanced for current needs or because they fail to address key pain points. CFTP minimizes this risk by grounding technological development in customer driven insights, ensuring that innovations are market relevant from the outset. In the aircraft powerplant case study, for instance, hydrogen based propulsion technologies emerged as a promising paradigm, but the decision to invest in this technology was heavily influenced by customer and regulatory demands for sustainability and low emissions.

2.3.3 - Challenges and limitations of CFTP

While CFTP offers many advantages, there are also challenges and limitations that firms need to navigate, particularly in the fluid phase of technological development. One of the main challenges is the difficulty in forecasting future needs. Customers may not always be able to articulate future needs, especially for disruptive technologies. In such cases, CFTP may be limited in its ability to forecast long term demand. For instance, in the development of blockchain technology, early customers may not have fully understood the potential of smart contracts and decentralized applications, which later became key features driving its adoption.

Balancing innovation with customer input is another challenge. There is a delicate balance between listening to customer feedback and pushing the boundaries of innovation. While customer feedback is crucial, it can sometimes limit a company's ability to pursue radical innovations that customers may not yet understand or be able to articulate. Companies need to be mindful of this balance to avoid stagnation or overly conservative technological investments.

Segmented market preferences present another difficulty in CFTP. In industries where customer needs vary widely across segments, CFTP can struggle to address the competing demands of different groups. For example, in the additive manufacturing space, one customer segment may prioritize precision, while another may prioritize speed and cost effectiveness. Developing a dominant design that satisfies all segments can be challenging, requiring companies to make strategic trade offs.

2.3.4 - The role of CFTP in identifying dominant designs

By aligning technology development with customer needs, CFTP plays a crucial role in the identification and emergence of dominant designs. When firms focus on technologies that deliver the greatest value to customers, they increase the likelihood that these technologies will become the standard in their respective markets. CFTP helps firms reduce uncertainty by continuously gathering customer feedback and aligning innovations with market needs, making it easier to predict which technologies will gain traction.

Moreover, technologies that are developed using a customer centered approach are more likely to gain widespread adoption, as they are more aligned with user expectations and create value for key customer segments. Companies that effectively leverage CFTP can shape the industry's direction by positioning their technology as the solution that best meets customer needs, pushing it toward becoming the dominant design.

2.4 - Limitations of existing models and the need for a new framework

The models and the approaches to methodologies covered in this chapter provide a sound platform upon which the dynamics governing the evolution of dominant designs can be understood. Abernathy-Utterback is a formal approach to analyzing the development of industries, and technology forecasting and Customer Focused Technology Planning (CFTP) are strategic approaches to predicting and defining technological trajectories. However, while these models have been instrumental in explaining past dominant design formation, their value in predicting future dominant designs remains to be achieved. Against the backdrop of increasing complexity of modern technological landscapes, where disruptive innovation, regulatory reform, and customer driven demands increasingly dominate, it is imperative to investigate whether it is feasible to develop a new, integrative model to enhance the prediction of dominant design formation across industries.

The next stage of this research attempts to break new ground in terms of existing theory by looking at real case studies where leading designs are still to be determined. Through this, we will test whether the principles outlined in this chapter are sufficient for prediction or whether a new approach is required to address the specific challenges of today's rapidly changing technology markets.

CHAPTER 3 – Case study presentation

After reading the existing theoretical models describing dominant design emergence, the following task is to check their applicability in real scenarios. In Chapter 3, six case studies will be presented, each stemming from a master's thesis where the emergence of a dominant design in different fields of technology has been investigated. These case studies provide detailed insight into how various industries handle the conflict among technological variants and the determinants that determine, in the end, which design prevails.

Each study applies a specific method of analysis to gauge the supremacy of one technological solution over another. Comparing across cases through this analysis, we will identify patterns and similarities across cases, paving the way to building a more generalized predictive framework for dominant design emergence.

3.1 - Dominant design in charging infrastructure

Bobirbek Kholmatov's thesis "Dominant Design in Charging Infrastructure: Identification of Technological Paradigm" revolves around the emergence of a dominant design for charging infrastructure of electric vehicles (EVs). The article discusses the transition to electric vehicles and the imperative role charging infrastructure has in bringing about the transition. It addresses the issues at hand, including the need for common interoperability standards, and proposes a method for early identification of a dominant design for this market. This involves analysis of different charging modes: home chargers, public fast chargers, battery swap, and wireless power transfer, and dialogue on customer liking, government policy, and technology trends.

The dominant design in EV charging infrastructure emerges through a combination of several factors:

1. Government regulation and policy: Government action is the most compelling incentive for the establishment of a leading design in EV charging infrastructure. Governments dictate the creation of regulation, providing subsidies, and allowing public charging infrastructure development. An example is the thesis citing that policy in the European Union and China has led to faster deployment of fast chargers, with such technologies gaining dominance in both areas. Safety standards are another factor that have an important role to play in determining charging technologies. Home charging points and public charging points must adhere to stringent safety standards for safe operation of charging devices. The thesis emphasizes the importance of regulatory mechanisms that enhance consistency and safety in different charging modes, which in turn enhances consumer confidence.

2. **Technology performance and customer preferences**: The performance of the various charging technologies, including charging speed, convenience, and availability, is a major factor influencing customer adoption. Technologies such as ultra-fast chargers that deliver high charging speeds are increasingly gaining popularity, particularly in public locations. In fact, charging time is one of the most significant factors

influencing the prevalence of different charging technologies. Customers prefer less charging time, ideally comparable to refilling a conventional vehicle. The ultra-fast charging and battery swapping technologies are favored because of their capability to minimize the charging time and are therefore competitive in the market. The viability of their application on a large scale is, however, still under consideration against the background of infrastructure cost and the stage of technological maturity.

3. **Cost efficiency:** Another important factor is the expense of deploying and operating the different modes of charging. Home chargers (Wall-Box) are being highlighted for being economical, especially since they allow users to charge their cars at a lower rate than from public facilities. Public fast charging and ultra-fast charging modes, although more expensive, are a necessity for individuals who cannot charge at home, and therefore are still integral to the whole EV system.

4. **Geographic and market specific adaptation**: The geographical location is a determining factor for the emergence of dominant designs. Economies like China and Europe are leading in utilizing fast chargers since they consist of many cities with concentrated urbanization and government led initiatives. The U.S. market, however, likes home charging since there is a higher availability of parking lots at home. This is very much connected with the availability of charging infrastructure that is key to customer satisfaction and technology uptake. The geographical distribution of EV charging infrastructure is key to the uptake of different technologies. The thesis evaluates the feasibility of having charging stations in urbanized regions with high population density compared to rural regions. For example, ultra-fast and fast charging will be more applicable for highway and urban networks while home charging would be more suitable for suburban or residential regions where proper parking spaces are available.

3.1.2 - Methodology

The method of assessment to determine whether a dominant design for EV charging infrastructure has emerged follows a systematic process to establish the most potential charging alternatives on technical, market, and regulatory bases. The analysis process has the following principal steps::

1. **Data collection and value chain mapping:** The study begins with having a broad set of facts regarding the four major categories of EV charging, their technical characteristics, infrastructure requirements, and value chain memberships. This in an attempt to gain a primal level of awareness of how each category of charging works and how they relate with traditional energy and transport systems.

2. **Customer driven assessment using Quality Function Deployment (QFD):** Customer preference and market competitiveness will be measured using the principles of Quality Function Deployment. Convenience, charging speed, cost, and availability of all charging modes will be studied. The features will be scored according to consumer requirement and market demand so that the most desired and competitive charging modes will be determined.

3. **Analysis of key determinants of market dominance:** Beyond consumer preferences, the study will examine external factors that influence the adoption and scalability of EV charging technologies. These include:

    - **Government policies and regulations:** The role of public policies, incentives, and infrastructure investments in shaping the competitive landscape of EV charging technologies.

    - **Technological comparison:** An evaluation of the efficiency, scalability, and long term viability of each charging method, considering factors such as energy efficiency, compatibility with vehicle manufacturers, and infrastructure feasibility.

4. **Integration of consumer and market factors for predictive analysis:** The results that are gathered through consumer driven evaluation (Step 2) and the determinants of market scope (Step 3) will be combined to provide a weighted measure of the potential for each charging type to become the future standard. The combined approach makes it possible to consider both demand factors and supply factors in making predictions as to which EV charging method will become the industry norm.

3.2- Dominant design in data centers

Short description of the thesis

The thesis "Prediction of the Dominant Instruction Set Architecture in Data Centers" by Mahammad Latifli focuses on the research of the conflict between the competing architectures CISC (Complex Instruction Set Computer) and RISC (Reduced Instruction Set Computer) within the framework of data centers. The research attempts to predict which of these architectures will be the dominant design in the near future considering their technological as well as market developments. Utilizing a meticulous comparative analysis of their technological features and market conditions, the thesis develops a framework to determine the eventual dominant design in this sector. The phenomenon of dominant design is discussed under both technological superiority and market conditions, providing insight into the likelihood of the transition from the current CISC to the new RISC design.

1. **Technological superiority**: The technology has to have a clear advantage when it comes to power consumption, efficiency, and overall performance. RISC architecture was significantly more power efficient than CISC, especially in the context of watts per request and joules per session. Benefits like these render RISC ideal for modern data centers, which employ less power consumption and faster speed. However, CISC with its complex instruction set still prevails universally since it is supported and has legacy for previous software.

2. **Market inertia and infrastructure**: CISC architecture therefore eliminates there with its huge installed base and compatibility with vast quantities of software. This generates a strong inertia that prevents new architectures like RISC from replacing it, even though they possess technical superiority. A new technology will need to be compatible with current assets if it is to make an easy transition. Due to this, complementary assets such as the support infrastructure in terms of the existence of compatible hardware and software ecosystems are crucial to the verification of the new technology.

3. **Strategic situation of the industry**: This includes the timing of market entry, dynamics of competition, and companies' ability to strategically position themselves within the market. RISC enjoys the benefit of entering a market that is more energy efficient oriented, which gives it strategic leverage over more established but energy hungry CISC architecture.

4. **Government regulations and institutional support**: Government policies, especially those in the sectors where energy conservation and carbon reduction become paramount, would bear significantly on implementing more energy efficient designs like RISC. Government policies favoring or mandating energy saving technology would see RISC arise compared to CISC.

5. **Cost of switching**: The thesis highlights the high switching costs associated with transitioning from CISC to RISC architecture. Data centers that are heavily invested in CISC based infrastructure may face significant costs in terms of hardware upgrades, software reconfiguration, and retraining staff. While switching costs can be high, the long term benefits, particularly in terms of power savings and reduced operating costs, make RISC an attractive option despite the initial investment .

6. **Appropriability regime**: This is referred to as the protective capabilities of how well the technology can be protected with patents, trade secrets, and intellectual property. A strong appropriability regime ensures that the innovators behind RISC protect their competitive advantage, with the technology thus maintaining its leadership in the market..

7. **Customers' point of view**: Ultimately, customer decision will be the clincher. As more companies emphasize energy efficiency and reducing costs, RISC's strengths in these areas make it increasingly appealing. Customer reaction regarding reliability, performance, and ease of integration will also decide which architecture will prevail.

3.2.1 - Methodology

This methodology is based on an integrative framework developed by F. Suarez, which analyzes the variables affecting market dominance according to the different phases of market evolution. The key distinction in this approach is that, instead of focusing on technology at the firm level, the emphasis will be placed on the industry level within an already established market, specifically considering the case of the CISC versus RISC battle.

With these specifications in consideration, one more framework derived from Suarez's work will be designed to examine the industry from its very inception. The purpose is to determine whether a particular technology has within it the necessary market conditions in the long run to lead the market.

In this method, the competing architectures will be contrasted head on and an estimate will be established of the probability with which the new architecture is expected to prevail. The analysis will be framed around the following principal considerations:

1. Technological comparison
2. Complementary assets
3. Strategic industry position
4. Governmental regulations and institutional interventions
5. Switching costs
6. Appropriability regime
7. Customers’ perspective

3.3 - Dominant design in autonomous driving vehicles

The thesis, titled "Methodology for the development of dominant design and analysis of the technology adoption process for autonomous driving", is authored by Paolo Bonivardo. The focus is on developing a methodology to identify the optimal dominant design for autonomous driving vehicles. It also examines the process of adopting this technology across different geographic markets. By putting forward the profound social and economic effects of autonomous driving technology that disrupts the classical paradigm of the automotive sector, it further goes into technical elements and consequently the importance of choosing the right dominant design to speed up the adoption of technology..

1**. Component performance and complexity**: The analysis compares three critical components LiDAR, cameras, and radar based on their performance. The thesis defines specific metrics of performance, such as computational complexity, object detection, object classification, and distance calculation, which is crucial in identifying that component that could emerge as the leading technology used in the autonomous vehicle. LiDAR, for example, offers high accuracy but comes with high computational demands, whereas radar is more cost effective but less precise. There will be a dominant design when one of these technologies becomes mature enough to be widely adopted. This means becoming standardized throughout the industry so everyone involved automakers, technology vendors, and governments agrees on a common solution.

2. **Adoption in urban vs. non-urban scenarios**: The viability of every technology component is analyzed across a range of driving environments. Radar, for example, would function better in extra urban areas where there are fewer obstacles, whereas LiDAR and camera technologies would function optimally in urban, densely populated areas. The flexibility of the different environments is also important in order to determine the ruling design.

4. **Government regulation and policy**: Government policy, particularly safety standards, privacy of data, and traffic law, plays a significant role in deciding which technology will dominate. Policy and regulatory frameworks also have a crucial role to play in opening or shutting the door on autonomous driving. Countries with codified laws for AVs in favor of these vehicles and proactive regulation of technology, such as the United States and Singapore, are apt to witness rapid adoption of a dominant design.

3. **Infrastructure**: Physical and technological infrastructure to accommodate AVs is also relatively varied between regions. States of the art technology infrastructure, communication networks, and innovation platforms are needed to access. Countries with mature innovation systems, including South Korea and Finland, are likely to adopt AVs. Countries lacking this infrastructure, like India and Brazil, are far less prepared.

4. **Consumer acceptance**: Social and cultural embrace of emerging technologies also affects the pace with which a leading design can emerge. Countries like the UAE and South Korea with more accepting populations towards cutting edge technologies are better positioned to make quicker adoption.

3.3.1 - Methodology

1. Methodology implementation steps

Definition of the technical features of the technology

Step one is defining a collection of N technical features describing the technology thoroughly. These should be as few as possible for manageability reasons but complete enough to offer an overall view of the technology's capabilities.

2. Definition of the technology's performance metrics

In order to quantify the importance of the technical characteristics which have been discovered, M performance indicators are constructed. These are tangible benefits to the final user and are given weights depending on their cumulative impact. The relationship between the technical characteristics and the performance indicators is structured into an N × M matrix, which provides a framework for technological performance measurement.

3. Evaluation of technical characteristics

Once the technical parameters and performance indicators are defined, each parameter is assigned a rating based on its connection to the indicators. The sum of the product of the normalized ratings and their respective estimated weights is the combined effect of each parameter. This allows the advantages and disadvantages of the technology to be quantified.

4. Analysis of semi quantitative variables

Besides the quantitative assessment of technical characteristics, other semi quantitative factors are considered to reflect the overall contextual factors influencing technology adoption.

- **Politics and legislation:** Represents a country's ability to adapt and implement regulatory changes necessary for the adoption of the technology.
- **Technology and innovation:** Measures the technological advancement and innovation rate of the country, with a particular focus on the relevant industry.
- **Infrastructure:** Evaluates the quality and readiness of the infrastructure necessary to support the technology's adoption and widespread implementation.
- **Consumer acceptance:** Assesses public perception, willingness to adopt the technology, and market readiness.
- **Economic impact:** Examines the potential financial and industrial effects of the technology, including cost implications, market disruption, and long term sustainability.

3.4 – Dominant design in aircraft powerplant industry

The thesis "Development of a method of analysis to identify emerging dominant designs in the aircraft powerplant industry" by Lorenzo Grivet Foiaia focuses on determining most likely dominant design for powerplants of aircraft through 2040. Financial sustainability and ecological sustainability are in mind because technology changes are made to enable the necessary elements thereof. The thesis addresses a systematic approach to forecasting which powerplant technology among current and future upcoming technologies will be most likely to dominate. The research is divided into three phases: the qualitative, the semi quantitative, and the quantitative, employing forecasting models to evaluate the performance and innovation trajectory of different technologies.

Emergence of dominant design and principal reasons

The dominant design in the aircraft powerplant industry is expected to emerge from a combination of key factors:

1. **Technological readiness**: The author estimates the technological maturity of powerplant technologies like hydrogen based and battery electric powerplants. The research points out that powerplants that utilize liquid hydrogen will be the future direction of design, particularly for medium and short ranges, as they are capable of clean energy production at the maturity of hydrogen technologies regarding storage and production. The research illustrates that hydrogen fuelled engines provide better efficiency and lesser emission

2. **Market segment needs**: The ability of each technology to adapt to different market segments (e.g., short haul vs. long haul flights) is another point of analysis. Different market segments, such as short range operations and long haul flights, have specific requirements for powerplant performance. Hydrogen technology is expected to satisfy the needs of operators interested in reducing carbon emissions and achieving operational efficiency for short to medium range flights, which are considered the most relevant in terms of traffic and emissions. Lastly, the author highlights customer demand for cleaner, more efficient powerplants, which aligns well with the strengths of hydrogen based and hybrid electric systems. The potential for reduced operating costs and compliance with future regulations makes these technologies attractive to operators.

3. **Government regulations and environmental pressure:** Increasing pressures from international regulation and green environmental policy aimed at the reductions in emissions will drive the market towards clean energy solutions. The environmental benefit of each technology contributes significantly to the consideration, with aiming reductions in CO_2 emissions at the core of the thinking. The powerplant based on hydrogen stands out by being able to take to the skies on zero carbon emissions, thus the high probability to be well supported under mooted regulations pushing towards sustainability.

4. Complementary assets and infrastructure: The thesis also points out the investment in refueling and maintenance infrastructure for planes. Each technology's necessary infrastructure is outlined by the author. Hydrogen refueling infrastructure is a challenge, yet long term emissions and fuel efficiency savings make it an appealing option. Battery electric technology, for as far as it entails widespread overhaul of infrastructure, is more feasible for short flights..

5. **Operational Costs and Efficiency:** The analysis includes detailed comparisons of operating expenses and energy efficiency across technologies. Battery electric configurations, for example, are widely praised for low operating expenses, but with limited range and excessive weight, less so for long range flying. Hydrogen fueled turbofans offer a compromise between range, fuel efficiency, and sustainability.

3.4.1 - Methodology

To deal with the uncertainty inherent in technological advancement, the model presented in this forecasting method employs a three step sequential process. The method combines quantitative analysis, based on empirical data, with qualitative and semi quantitative assessment to obtain an overall assessment. Technology Forecasting and Customer Focused Technology Planning (CFTP) methodologies are employed by the model to assess technological competitors in a systematic way and predict the arrival of a dominant design.

1. Qualitative analysis

This phase aims to establish a foundational understanding of the technological landscape by mapping market conditions, competing technologies, and supporting infrastructure.

- **Market profile development:**
  A **Product Market Map** It develops a Product Market Map to provide a structured outline of product spaces, market drivers, and competitiveness. This activity describes key trends, future opportunities, and external factors affecting the adoption of technologies.
- **Focal technology assessment:**
  A solution tree is constructed to structure competing technologies and their variants. Each fundamental technology is analyzed in more detail based on a block diagram that determines its key architectural components and their dependencies. Through a systemic process, this facilitates the consideration of technological alternatives and their prospectives in an easier manner..
- **Complementary assets evaluation:**
  Supporting infrastructure, supply networks, and complementary technologies are available and appreciated to measure readiness of an ecosystem. This exercise identifies likely barriers for widespread adoption and to what extent complementary assets existing can facilitate scaling of a specific technology.

2. Semi quantitative analysis

At this stage, the most important technological elements are examined with the aid of formal models of assessing interdependencies, market compatibility, and innovation potential.

- **Lead Lag correlation analysis:**
  Using this approach, the strongest technical interdependencies between a specified starting point technology and proximate innovations are found. Based on how a technology responds and adapts to the environment, its adoption probability and long term viability can be determined.
- **Technology market interaction matrix:**
  By analogy with the CFTP process, this step uses a Technology Market Interaction Map to study the extent to which different technologies match customer need and want in high interest market niches. This plots technological innovation against true demand, with higher potential for take-up.
- **Technology impact mapping:**
  Altered from the CFTP Technology Investment Opportunities Identification process, this step assesses ingredient and process technologies on their potential to meet market needs and how mature and ready for commercialization they are.
  By combining these perspectives, the research provides a structured examination of how different technologies make their claim in the competitive marketplace.

3. Quantitative analysis

At this level, the performance models are established to forecast industry trends and technological developments..

- **Performance curves forecasting:**
  Future substitute technology performance curves are estimated using a three step approach:

  1. Development of a performance indicator: a composite metric is created for the measurement of technological advancement over time
  2. Evaluation of performance trends: the exponential growth model of Technology Forecasting is applied to historical data, providing an evidence based projection of future developments.
  3. Sensitivity analysis: different growth rates are modeled to simulate various adoption scenarios, accounting for uncertainties in market acceptance, R&D investment, and regulatory shifts.

- **Rate of innovation curves:**
  To determine the rate of technological advancement, rate of innovation curves are constructed based on the Abernathy and Utterback Model. The curves distinguish between product innovation rate and process innovation rate.

4. Results refinement

The final step incorporates the forecasting analysis to identify the projected technological paradigm that will emerge based on the expected dominant design. Key points addressed are:

• Technological enablers of the successful design, such as cost savings, efficiency improvement, and integration into an ecosystem.

• Forces of market and industry enabling adoption, including regulatory activity, competitive action, and cost feasibility.

• Possible disruptions that may change the course, i.e., future innovations or shifts in consumer behavior.

This step includes critical analysis of the forecast results so that the patterns of industry change and competition are better known. Through employing such a systematic methodology, businesses are able to decide strategically upon the technologies in which to invest, forecast probable risk, and address technology life cycle uncertainty.

3.5 - Dominant design in flying cars

The thesis "Identification of an emerging dominant design: The flying cars" by Tiziano Tancredi focuses on the identification of the most prospective emerging dominant design for flying cars. The research covers some prototypes and ongoing projects by leading players in the industry, using a Quality Function Deployment (QFD) motivated approach to classify various typologies of flying cars. The assignment is to determine which technology design will be likely to prevail on technical, market, and social grounds with specific reference to safety, cost, environmental impact, and social acceptability.

Emergence of the dominant design and principal reasons

The thesis identifies several key factors contributing to the emergence of a dominant design in flying car technology:

1. **Technological types**: The author classifies flying cars into two broad categories human piloted and self-piloted cars. The technical performance of both the types is compared based on different factors of operation such as the number of passengers, airspace capacity (operating altitude of the vehicle), and the geographic features most suitable to each category. VTOL (Vertical Take-Off and Landing) cars are highlighted due to their ability to excel in urban environments without requiring extensive runways. Capacity and range distance are the two major technical sections explored. Flying car capacity is a serious matter to consider, particularly in looking at whether or not they would be able to fit into a range of markets. The research shows that most flying cars are constructed in 2-seater configurations, best suited for private and commercial use in urban cities. Larger capacities (3 to 7-seaters) are being researched for specific uses like taxis and cargo transportation but are too costly and complicated for common use. Flying cars are quantified in terms of their operational range. Human driven cars have a medium to long range (around 80 km to 322 km), and hence are best suited for long commutes and freight transport. Autonomous drones, on the other hand, have short ranges (around 104 km), and hence are best suited for short city commutes or emergency response within the city.

2. **Market segmentation**: The four broad market segments are military, private, commercial, and professional markets. Each of these segments has certain requirements, and flying cars are assessed based on how well they satisfy those requirements. For instance, military applications may emphasize reliability and operational flexibility, while private and commercial markets emphasize safety, affordability, and social acceptability. The analysis also notes that VTOL configurations of lower seating capacities (typically 2-seaters) are optimal for commercial and private use in densely populated urban areas. These aircraft address traffic jams and are easier to deploy compared to larger multi-seater configurations.

3. **Geographic impact**: Different regions show different interests in flying car technology. North America and the Asia Pacific region are expected to be the most likely regions for early adoption of flying cars because of their urban density and technological readiness. The paper determines required social, legislative, and economic conditions in these regions to support the development and launch of flying car technology. These regions suffer from extreme urban congestion, which can be relieved by flying cars. Less developed regions, however, may not have the infrastructure or demand for early adoption.

4. **Regulatory and safety considerations**: Regulatory and safety concerns are viewed as the biggest barriers to mass adoption. Technologies capable of addressing safety issues such as advanced tracking systems to prevent mid-air collisions are more likely to succeed. Social acceptance will also depend highly on successful take-up of robust safety features, particularly in densely populated city centres. Regulation of the airspace along which flying cars move is also a major issue. Human operated vehicles will operate in medium altitude air space (typically below 600 meters), far from the busy near ground environment, hence minimizing interference with urban life. Autonomous drones are designed to operate in low altitude air space, where visibility is better.

5. **Environmental impact and sustainability**: The growing demand for green transportation systems places electric powered flying cars at the forefront of the technological race. Electric push, as opposed to hydrocarbon fuel, is greener and in accordance with global trends of pollution and noise control. As electric battery technology continues to advance, it stands likely to play a significant role in driving the superiority of some designs..

6. **Cost and infrastructure considerations**: The conclusion also refers to the very costly nature of mass deployment of flying car technologies. However, intervention by the public sector, particularly in infrastructure development, can serve to offset such costs in the long run. The technological innovations needed for safe and reliable utilization of flying cars will also continue to be a focus area for future R&D.

3.5.1 - Methodology

The methodology follows a step by step approach to analyse the primary typologies of flying cars and determine their potential for dominance in the transportation sector.

1. Data collection and literature review

- Identification and compilation of academic papers, market reports, and industry analyses regarding flying car technologies.
- Review of case studies, patents, and regulatory policies influencing the adoption of aerial vehicles.

2. Classification framework for flying cars

To systematically analyze flying cars, a classification framework is developed based on three key dimensions: carrying, geographical scope and travel distance. Each classification mode is assessed based on a pros and cons/risk analysis, identifying key technological, regulatory, and economic challenges.

3. Market segmentation and comparative evaluation

A structured matrix is developed to evaluate manned and unmanned flying cars across four macro segments: Military Applications, Private Ownership, Commercial Operations, Professional and Industrial Uses

Each segment is analyzed based on: adoption feasibility, market potential e risk assessment

By weighting and evaluating these aspects for both piloted and autonomous aerial vehicles, a scoring framework is established to determine the likelihood of a particular category achieving dominance.

4. Market dimension analysis and R&D investment insights

Analysis of the different market dimensions and some additional insights regarding R&D investments related to transportation

3.6 - Dominant design in additive manufacturing

The thesis "Additive Manufacturing: identificazione e modellizzazione del paradigma tecnologico" is an identification and modeling study of technological paradigms applied to additive manufacturing (AM) or 3D printing technology. The study focuses on achieving an understanding of the effects different 3D printing technologies have had on various industries such as the aerospace, automobile, and medical industries. The thesis would love to determine what technology has the potential to emerge as a dominant design a prominent standard that can end up being universally accepted in these industries. Through an elaborate research on the performance measurements, technical features, and applications in different industries, the study would love to devise a model that predicts the dominant design.

Emergence of the dominant design and principal reasons

1. Technological maturity and versatility: The thesis argues that Stereolithography (SLA), Selective Laser Sintering (SLS), and Fused Deposition Modeling (FDM) are most likely to be the leading technologies in their respective markets. These technologies have already demonstrated themselves in precision, affordability, and versatility to other applications and materials, and are thus likely contenders to become top designs in markets like aerospace and medical device manufacturing.

2. Market and sector specific adoption: All 3D printing technologies have certain strengths that most optimally fulfill the needs of specific industries. SLA, for example, is utilized to make extremely accurate, isotropic components in the fields of medical devices and jewelry. FDM offers more productivity and is better suited to do so.

3. Economic feasibility and infrastructure: production cost, material and operating costs, is a determining factor as to what technology will dominate. Technologies that have low resource requirements but high quality output will be implemented on a large scale in cost sensitive markets like consumer electronics.

These are the determinants of the leading design, which will most likely be established on the ability of a given 3D printing technology to satisfy industry specific needs while remaining economically viable and sustainable.

3.6.1 - Methodology

1. Collecting initiatives and screening into use cases

The first step in the methodology involves collecting initiatives related to the evolution of 3D printing technologies. These initiatives are screened and categorized into distinct use cases to ensure a comprehensive evaluation of technological advancements across various industrial sectors.

2. Evaluation of performance indicators

To measure the relevance of 3D printers within different use cases, performance indicators are identified and assessed. This process includes:

- Analysing key parameters that determine the effectiveness of 3D printers in each industrial sector.
- Developing a row vector for each industrial sector, with performance indicators weighted on a qualitative scale from 1 to 10 based on their relevance.

3. Definition of technical characteristics

The technical characteristics of each 3D printer are quantitatively defined. These characteristics (denoted as n) serve as a basis for describing the operational performance of different printer models (denoted as s).

The identified technical characteristics provide an objective framework for assessing each printer's capabilities.

4. Rationalization of technical characteristics

Once the technical characteristics have been listed, they are correlated with specific additive manufacturing (AM) technologies. The correlation process follows three reference ranges to facilitate a structured comparison of printers across different AM technologies. This step ensures that each printer's attributes align with the broader classification of AM technologies.

5. Evaluation of AM technologies in relation to performance indicators

To evaluate the adequacy of each printer model for specific use cases, an m x s matrix is created, where:

- **m** represents the number of performance indicators.
- **s** represents the number of printers analyzed.

Each printer is assessed based on its correlation with performance indicators. This evaluation is conducted using the dot product of technical characteristics and relevant indicators. Additionally, the correlation is weighted to maintain objectivity and prevent distortions in the final evaluation results.

3.7 - Identification of common themes across industries

The analysis of six different case studies in a variety of industries found a set of key themes that exert a significant effect on the evolution of dominant designs. These themes consistently have a significant effect on what technologies dominate, although the weighting and effect of each factor will vary by industry context.

1. Government regulation and Policy

Government policy and regulation have a dynamic role in promoting technology adoption and dominant design formation. Government intervention through the provision of subsidies, safety regulation, regulatory policies, and stimuli to the market can stimulate the development and application of certain technologies, or slow it down.

Governments can provide subsidies or tax relief to reduce the burden on consumers and producers and make certain technologies more attractive. Safety regulations are also crucial as they ensure dependability and consumer trust, making it possible for widespread adoption. Additionally, environmental regulations mandating reduced emissions or efficiency can have a direct impact on the viability of alternative technologies, typically favoring designs that are compliant with such policies. Government policies therefore function as both facilitators and gatekeepers to create market conditions that are appropriate for the establishment of dominant designs.

2. Technological superiority and performance

The emergence of a dominant design is often closely linked with its technological superiority over other options available. Performance characteristics such as efficiency in energy consumption, speed, accuracy, and reliability are important determinants of industry choice and consumer acceptance. A technology that excels over its rivals on these aspects is most likely to dominate because it offers higher utility and is better aligned with the evolving needs of the industry.

Technological flexibility also plays a crucial role. A design that has the flexibility to find use in multiple applications or industries is more likely to gain momentum and become the standard. For instance, technologies that deliver improved performance in reliability or accuracy are more appealing in industries where these qualities are most highly regarded, and technologies with broad application potential can spread across industries, increasing the chances of it emerging as the technology of choice. Scalability the ability of a technology to be scaled up to cater to growing demand without loss of efficiency is another critical aspect of technological superiority, and it plays an important part in the acceptance of a design.

3. Market and customer preferences

The alignment of a technology with customer needs and market demands is key to defining the emergence of a dominant design. Customer needs, such as ease of use, cost efficiency, speed, and convenience, are key to determining which technology gains widespread adoption.

For a technology to become dominant, it will have to provide apparent value to the consumer, outperforming their specific needs more than the rest. Such as low operating costs, compatibility with existing systems, and improved user interface are in this category. Also, market segmentation, customer requirement segmentation within sub markets, can also decide the rate at which a design emerges. Technologies that well cater to the niche segments, but remain relevant to broader markets, are best positioned to become dominant.

Besides, customer acceptance and early market feedback can create network effects, whereby the value of the technology rises with more people employing it, reinforcing its position as the standard choice.

Customer need satisfaction, both in performance characteristics and overall experience, is thus critical in the journey to dominance.

4. Complementary assets and ecosystem readiness

The presence and development of complementary assets and preparedness of the overall ecosystem are determinants to enable the emergence of the dominant design. Complementary assets refer to the technologies, infrastructures, or services that provide additional utility and usability to the fundamental technology. These may be maintenance depots, software ecosystems, charging infrastructure, or mass supply chains for mass production.
For a technology to be a dominant design, it must be supported by an ecosystem that ensures seamless integration, enhances performance, and fosters scalability. Having readily available a mature infrastructure that can accommodate the new technology is a wonderful means of accelerating its adoption.

5. Cost efficiency and economic feasibility

Its economic feasibility both in terms of the initial investment of deployment as well as ongoing operating expenses plays a major role in its application. Technologies that offer the best of both high performance and cost efficiency, have the highest likelihood of becoming dominant, since they deliver maximum value to the producers and consumers alike.

Cost of deployment considers aspects such as manufacturing, infrastructure development, and deployment of technology. Technologies that have minimal initial investment or can be plugged into already established infrastructure with little change are normally favored, especially in capital sensitive sectors. Running costs such as energy consumption, maintenance, and support services also matter because they influence long term viability of the technology.

Second, cost effectiveness must accompany scalability technologies that cost effective to scale up are more attractive as flagship designs. As industries are converging towards mass adoption, holding costs while having the ability to meet increasing demand is paramount. That means a technology not only needs to be affordable initially but needs to remain cost effective as volume increases.

Switching cost is another significant consideration. If the entry cost into the market and replacement of older technology is high, customers will not switch.

CHAPTER 4 - Analysis

Following the case study analyses presented in Chapter 3, Chapter 4 will examine a broader examination of the common themes emerged from different industries. While there was a clear environment and set of influences impacting each use case examined within the previous chapter, several common elements played a recurring role throughout, always playing a crucial part in the development of dominant designs.

Here in this chapter, we are going to move methodically through these broad themes technological dominance, economic feasibility, regulatory and policy influence, complementary assets, and customer preferences. In contrast to their relative impact in different technological fields, we try to identify their impact on which designs prevail and how these themes engage in other market regimes

4.1 – The role of government regulation in the emergence of dominant design

Public policy and regulation tend to be pivotal drivers of influencing directions of technology adoption and, in turn, securing dominant designs. In a variety of mechanisms subsidy, requirements for safety, requirements for regulations, and incentives from markets governments have the potential to promote or limit the arising and spreading of particular technologies. The interventions create an environment supporting certain designs while limiting others, ultimately culminating in decisions on which technologies obtain dominance.

Although technological dominance and marketplace forces are traditionally cited as initiators of premier designs, government cannot be dismissed. Policymaker friendly policy to encourage innovation, drive safety, or target environmental goals often serve as catalysts and gatekeepers, determining what becomes fashionable and what cannot get a toehold. However, government intervention is a double edged sword: it can initiate development and redirect industries to preferred locations but will inevitably have unforeseen consequences such as market distortions or premature technological lock in.

Governments influence the emergence of dominant designs through the application of different direct and indirect mechanisms. The mechanisms determine the market forces, technological innovation, and consumer trends accountable for the triumph or failure of competing technologies.

4.1.1 - Financial incentives

Maybe the easiest way in which governments can influence the adoption of technologies is by making financial incentives. These include public support for R&D, and subsidies and tax credits. In reducing the financial burden on consumers and producers alike, financial incentives can help get new technologies up to economies of scale sooner and hence more probably be dominant.
For example, in the electric vehicle (EV) industry, state subsidies have fueled EV deployment in regions like China, the United States, and the European Union. Both consumer and manufacturing subsidies have not only enhanced the economics of EVs to reduce their cost, but have even tipped the lithium ion battery towards dominating over competing options such as hydrogen fuel cells. Just as in tax incentives stimulating the adoption of renewable energy technology.
Governments further drive top designs through publicly funded R&D. They can accelerate the development and confer some designs with a competitive advantage by investing in specific technologies.

4.1.2 - Regulatory Standards

Regulations serve a double purpose in the emergence of dominant designs. They facilitate technology adoption by ensuring safety, reliability, and consumer confidence. At the same time, they serve as barriers to entry for competing designs, inclined to promote a technology over another through mandated interoperability and compatibility standards.

Wherever safety issues take precedence, regulation standards can go a long way in determining which technologies come to dominate. The aeronautics industry, for instance, is subject to stringent safety measures by organizations like the Federal Aviation Administration (FAA) and the European Union Aviation Safety Agency (EASA), which steer the development and adoption of new engine technologies such as hydrogen fuel powerplants. These technologies must undergo intense safety testing and certification processes, which can accelerate their adoption or retard their development depending on the regulatory outcomes.

On the contrary, regulatory bodies can also deter the creation of substitute designs. For autonomous driving technologies, for example, stringent safety standards and backup safety features have stalled the deployment of fully autonomous cars. As such, incremental automation technologies such as Level 2 and Level 3 Advanced Driver Assistance Systems (ADAS) have been the in between dominant designs, postponing the creation of fully autonomous solutions.

4.1.3 - Environmental regulations

Governments get involved as well through environmental policy, frequently delineating competitive circumstances for technologies supporting sustainability goals. Such policies may determine what the sustainable versions of these are over the long term, and particularly where it is the energy efficiency and carbon emission areas that dominate concerns.
For example, the European Union's ban on internal combustion engine (ICE) cars by 2035 de facto assures the dominance of electric and hydrogen fuel based cars in the auto industry. Similarly, energy efficiency standards have pushed the adoption of power intensive technology alternatives.
Governments implement waste reduction and circular economy policies to influence dominant designs.

4.1.4 - Government procurement and large scale investments

Government spending on public infrastructure and large government procurement has the ability to induce de facto standards leading to dominant designs. When government is a large buyer of technology, it can create industry standards in its own acquisitions.
Similarly, large infrastructure schemes can lock in particular technologies as design leaders due to their upfront capital investment and long term lifespan.

4.1.5 - Unintended consequences of government regulation on dominant design

While government intervention is likely to induce technological progress and enable dominant designs, it also has the tendency to create unwanted competition distortions. These distortions have a tendency to induce premature lock in, innovation that is suppressed, and market fragmentation that discourages the entry of more efficient technologies.

4.1.6 - Market distortions and premature lock in

Subsidies by the government sometimes lead to premature lock in of not the most efficient and sustainable technologies in the long run. If a government subsidizes a technology heavily, then it becomes dominant even when there is a better alternative.

An example of this is the U.S. ethanol biofuel subsidies. While ethanol had been presented as a renewable alternative to gasoline, the subsidies distorted the market in favor of ethanol at the cost of more energy dense biofuels. Not only did this increase food prices due to demand for corn, but it also failed to deliver significant long term environmental benefit compared to other renewable fuels..

4.1.7 - Overregulation slowing innovation

Over regulation suppresses competition and deters new designs to emerge. Since regulatory frameworks progressively become more restrictive, new technology is discouraged to be introduced to the market while instead concentrating on incremental design developments instead of development of new designs.
For instance, FAA regulations in the commercial aviation industry have led to a slowdown of the manufacturing of electric vertical takeoff and landing (eVTOL) aircraft. As much as there is great potential for eVTOL technology to revolutionize urban air mobility, meeting high safety and certification requirements has in the past slowed down the development of a revolutionary idea in the industry.

4.1.8 - Technology nationalism and market fragmentation

Regulatory policy differences among countries can impede the establishment of international standards and cause fragmentation and reduced cooperation among markets. This technology nationalism can suppress the widespread take up of one dominant design.

4.2 - The role of technological superiority in the emergence of dominant design

A dominant design is also influenced by an array of forces, including market demand, regulatory policy, and consumer desire. But perhaps the most elemental driving force of technological dominance is technological superiority the extent to which a technology beats out others in terms of efficiency, flexibility, and scalability. A technology with compelling strength in these dimensions has a higher likelihood of being widely adopted and becoming the industry standard.

Although more technical excellence can provide a competitive advantage, historical experience indicates that technical superiority alone is not always sufficient. Other exogenous influences like lock in effects, infrastructure readiness, regulatory barriers, and timing in the market may lead to a superior technology being embraced rapidly or allow a lower quality but better positioned rival to become the leader. This section explores the role of technological superiority in shaping dominant designs by analyzing three key dimensions:

1. **Performance**: The extent to which a technology provides higher efficiency, speed, accuracy, or reliability than competing alternatives.
2. **Versatility**: The ability of a technology to adapt across multiple industries and applications, increasing its overall adoption potential.
3. **Scalability**: The extent to which a technology can expand to meet growing market demand without efficiency losses, ensuring long term sustainability.

By examining these dimensions in detail, supported by industry case studies and counterexamples, this section clarifies how technological superiority contributes to the emergence of dominant designs.

4.2.1 - Mechanisms through which technological superiority drives dominance

Performance

At its most fundamental, superior performance over the options of the day is among the very reasons a technology becomes successful. Quicker processing, less power to consume, increased accuracy, or enhanced reliability are all areas in which performance upgrades tend to be a more compelling value proposition to commerce and consumers.

One good example is competition among different chemistries used in electric vehicles (EVs). Lithium ion (Li ion) batteries emerged as the design of choice due to increased energy density, longer life, and quicker recharging compared to the alternatives of nickel metal hydride (NiMH) batteries and hydrogen fuel cells.

These performance parameters made Li ion batteries the design of choice for automakers who drove economies of scale and cost reductions further entrenching their grip.

Performance alone is not enough to lead to success, however. The supersonic Concorde airplane was a technological wonder of never previously achieved commercial airline speeds. With improved performance, however, the Concorde could not become the ubiquitous airplane design due to the reasons of prohibitively high operation expenses, sound ceiling restrictions, and few passengers to fill. This illustrates that economic feasibility and demand have to accompany performance advantages in order to become universally accepted.

Versatility

While high performance within a single application is desirable, technologies flexible enough to be applied across numerous disparate industries or useful for a large number of use cases have much greater likelihoods of achieving dominance. Flexibility enables a technology to span its initial market, and it will be more likely to become the standard.

A classic case of versatility resulting in dominance is 3D printing (additive manufacturing). Initially developed to augment rapid prototyping, 3D printing technologies have branched out into various sectors. The flexibility of 3D printing technologies (e.g., stereolithography (SLA) and selective laser sintering (SLS)) to be adaptable with different materials and production needs has been very important in their widespread application.

Conversely, hydrogen fuel cells, with their extensive use in transport, energy storage, and industrial energy, have also not been able to assert dominance in transport markets. Their potential for emissions free transportation is still less affordable with enormous investments in infrastructure. The argument highlights here that flexibility of application by itself can be insufficient for dominance economic viability as well as ease of adoption become equally critical.

Scalability

For success in the long term, a technology has to be scalable, scalable means that it can expand without rising in cost disproportionately or in loss of efficiency. Scalability becomes imperative for expanding sectors rapidly, where a technology has to match with exponentially rising demand without a reduction in performance.

One of the finest examples of dominance by scalability is cloud computing. Amazon Web Services (AWS), Microsoft Azure, and Google Cloud have all emerged as market leaders by offering on demand computing capacity that scales beautifully from small businesses to large enterprises. Their ability to manage massive loads while keeping costs low has made them the infrastructure providers of choice for today's IT infrastructure.

Another example is the prevalence of Reduced Instruction Set Computing (RISC) processors in data centers. RISC based processors have become more popular because they are more power efficient and scalable than traditional Complex Instruction Set Computing (CISC) architectures. As data centers need more processing capacity with less power consumption, RISC based processors have become the processor of choice, proving that scalability is the key to long term dominance.

4.2.2 - Technological superiority as a multidimensional concept

Technological dominance is a multi-dimensional concept rather than a uni-dimensional one: it is a combination of performance, versatility, and scalability. Dominance in technology does not guarantee leadership regulatory frameworks, infrastructure, limits on consumer choice, and market momentum must be factored in as well. One needs to understand this interplay in order to predict the emergence of dominant designs an shape industry forms in advance.

4.3 - The role of economic feasibility in the emergence of dominant designs

The emergence of a dominant design typically follows factors such as technological superiority and encouragement from the regulators. Economic viability, however, is also an important factor in determining which technologies find widespread usage. A number of technologically superior innovations have never made it as market leaders since their cost profiles were not viable, whereas economically viable though inferior alternatives flourished. Economic feasibility is not just a matter of cost but encompasses the cost of deployment, ongoing costs, and how a technology can scale economically as demand grows.

This section describes the contribution of economic viability in the determination of pioneer designs in multiple industries through case studies in electric vehicle charging networks, data center design, autonomous vehicles, aircraft powerplants, flying cars, and additive manufacturing. This chapter uses failed and successful technologies in describing the economic factors underlying the creation of technology.

4.3.1 - Initial deployment costs

Whenever any new technology is brought into the market, the cost of deployment is typically a very big hurdle. These include research and development (R&D), production, infrastructure installation, and deployment. Technologies that have gigantic upfront costs can never make it to the marketplace, particularly where capital is limited or risk aversion is present to a large extent.

One of the most representative examples is that of the contest between different modes of electric vehicles (EVs) charging. During the pioneering times of EV penetration, the different modes of charging residential charging, public fast charge, battery swapping stations, and wireless charge fought with each other.
Battery swapping had a huge advantage of reducing charging time with the potential to replace depleted batteries with fully charged ones in a matter of minutes. Its high deployment cost posed a monumental economic barrier, however. Battery switching stations required advanced mechanical infrastructure, large stocks of expensive batteries, and substantial real estate investments. In addition to this, the lack of standardization of batteries among EV models contributed additional costs, making mass adoption unthinkable.

Conversely, fast charging evolved as the widespread design, not necessarily through a superior technology but through an economics of deployment: they were easier to deploy as they used infrastructure that could already be existing. Fast chargers were simpler to install on top of preexisting parking lots, required less specialized equipment, and had incrementally increasing infrastructure investment. These economic advantages, along with government subsidies in markets such as China and the European Union, made fast chargers the dominant solution even though they charged a bit slower than battery swapping.

It was the same for the war between RISC and CISC architectures in the data center. While RISC architectures consumed less power and delivered more performance per watt than CISC architectures, it was not cheap to make the transition from CISC to RISC. Organizations would have to invest lots of money in new hardware, software rewriting, and retraining people. The expensive switching costs imposed economic pain that kept CISC at the top for decades. Only when long term RISC benefits became obvious did the trend finally reverse.

4.3.2 - Operational costs

While deployment costs determine whether a technology can enter the market, operational costs dictate whether it can maintain dominance. Technologies that are expensive to maintain, energy intensive, or require frequent servicing often struggle to sustain market leadership.
This problem comes out in the competition among autonomous driving technologies. Various companies have experimented with various sensor systems, from LiDAR, radar, to camera based systems. LiDAR is exceptional in terms of high accuracy and the ability to construct rich 3D maps and is regarded as the gold standard for autonomous driving. However, the high operating cost is a gigantic issue. LiDAR systems are expensive to manufacture, require regular calibration, and consume more power than radar and camera based systems, contributing to overall vehicle cost

In contrast, camera and radar technologies are lower cost to manufacture and service. They are easier to integrate within current car configurations, draw lower power, and are more resistant to rough actual use. Even if less accurate under some conditions than LiDAR, cost savings have rendered them the love child of most auto manufacturers and given weight to the argument that low cost operating technology will eventually prevail.

There is a similar economic trade off in green aviation. The struggle between hydrogen powerplants and battery electric drive highlights the importance of cost of operation to technology adoption. Hydrogen fuel cells are very high in energy density and potential for zero emission flight, but expensive production of hydrogen and need for specialized refueling infrastructure pose enormous economic challenges. Meanwhile, battery electric systems, while range constrained, are cheaper to operate since they have fewer components, need less maintenance, and the price of lithium ion batteries is falling. Further down the road, when hydrogen production costs fall and infrastructure problems are settled, hydrogen based propulsion could be the norm for medium range flights.

4.3.3 - Scalability

For a technology to transition from a niche innovation to a dominant design, it must be scalable. Scalability refers to the ability of a technology to accommodate increasing demand without disproportionately raising costs. Technologies that achieve economies of scale, where unit costs decrease as production levels rise, are likely to dominate.

This is exemplified with additive manufacturing (3D printing). Methods such as Stereolithography (SLA) and Selective Laser Sintering (SLS) are very precise and widely used in niche areas such as aerospace and medicine. They are constrained in scalability, however, by costly material, low volume, and long post processing times. While Fused Deposition Modeling (FDM) is less precise, it is scalable in the sense that it is less expensive to make material wise and in mass production. Its economic advantage has seen FDM transition from prototype to consumer goods and vehicle manufacturing and forms part of the top designs in the greater 3D printing industry.

The new market of aerial cars brings another case of the scalability barrier. Human controlled aerial vehicles have more economic viability currently because they can leverage existing aviation infrastructure and regulations to economize on deployment costs. Autonomous aerial vehicles, although optimal for efficiency as well as safety, involves higher levels of research and development costs, regulatory barriers, and the cost of entirely different air traffic regulation systems. As autonomous flying car technologies improve and regulatory frameworks mature, the economics of mass producing autonomous flying cars may decline, making them the dominant design in the future.

4.3.4 - The cost performance trade-off

The theme shared by most industries is compromising on performance versus cost. A poorly performing low cost technology will never gain acceptance, and a highly performing but very costly technology will never be generally accepted in the market. A successful dominant design is one that compromises in the middle, giving enough performance for a price that the target market can absorb.

The death of battery swapping technology in the EV industry is an archetypal demonstration of this law. Though battery swapping solved the worst problem of charging time, the subsequent cost of infrastructure and simplicity in managing battery inventories made it economically absurd. DC fast chargers, though slower than battery swapping, were cheaper. They were less costly to install, needed less special equipment, and could be incorporated into existing buildings. This combination of low cost and acceptable performance led to their domination of the EV charging world.

4.3.5 - Economic feasibility

Out of a wide range of industries that include electric vehicles, data centers, and autonomous driving to aviation, flying cars, and additive manufacturing, economic feasibility always determines which technologies gain supremacy. Technologies that maintain deployment costs low, possess relatively affordable operational costs, scale effectively, and deliver sufficient performance are more likely to win.

Although technology leadership, governmental subsidies, and consumer needs push adoption, they will generally depend upon the financial viability of the technology. Ultimately, it is not always the latest technology that succeeds but the one that provides best value, be it a trade-off of performance, cost, and scalability and shapes the directions of industries for the future.

4.4 - The role of customer preferences in the emergence of dominant designs

The achievement of a technology to emerge as a dominant design has great dependency on its ability to fulfil customer requirements. People are worried about the cost effectiveness, usability, dependability, and availability of something, and technologies that can adapt to these specifications have more chances of being adopted by the masses. Technical supremacy is very important, but how a technology conforms to the needs of the consumers and market factors ultimately determine its dominance.

Consumer centric drivers of dominant designs

1. Convenience and accessibility
   Customers will always prefer those technologies that sit perfectly within existing habits and infrastructure. For the electric vehicle (EV) sector, fast charging replaced battery swapping since customers valued convenience of access to charging stations over the speed benefit of battery swapping. Battery swapping required standardized batteries and specialized stations, but fast charging supported multiple EV models and existing power grids.

2. Cost effectiveness and perceived value
   Although a technology may be more performance focused, customers will choose the one with the highest cost to benefit ratio. Within data centers, RISC based processors were more energy efficient than CISC processors, but businesses initially did not jump at it since the expense of porting software and infrastructure was significant.

3. Familiarity and trust
   Consumers like familiar and trusted technologies, particularly where safety and user friendliness are paramount. In the market for autonomous cars, camera based technology took over from LiDAR based technology, even though LiDAR technology is more precise. Consumers trusted camera based automation as a continuation of human driving, while LiDAR seemed foreign and costly. A 2023 SAE

International survey found 62% of drivers preferred camera based automation and 28% of them put their trust in LiDAR technology, predominantly due to the cost factor and lack of familiarity.

4. Network effects and user communities
   Technologies that build strong customer ecosystems are subject to network effects, with increasing adoption bringing more value. Fused Deposition Modeling (FDM) printers dominated 3D printing not because they were technically better, but because of huge user base, low cost materials, and open source development. As more people used FDM, manufacturers had an incentive to improve materials and software, cementing its dominance. FDM represented 70% of the industrial 3D printing in 2023, with SLA and SLS being more accurate.

Dominant designs are not just an outcome of technological superiority but also the degree to which they satisfy customer needs with respect to cost, convenience, and familiarity. Whether it is electric vehicle fast charging, ARM processors for data centers, camera based self driving in vehicles, or FDM printing, the value and ease of use perceived by the customer is what ultimately determines technology success. Companies that continue to innovate their offerings to address customer needs are well positioned to design dominant designs .

4.5 - The role of complementary assets in the emergence of dominant designs

Technological innovation is not a singular event. Even the most advanced and technologically capable technology will struggle to become popular if the necessary infrastructure, services, and enabling technologies are not present. This is where complementary assets and general ecosystem readiness come into play as far as whether or not a technology will achieve dominance.

Complementary assets are all the other constituents whether physical infrastructure, software platforms, supply chains, or service networks that render a core technology more usable and scalable. In their absence, even a good innovation can be stuck, liable to adoption barriers that prevent it from reaching critical mass. Ecosystem readiness, however, is a measure of how prepared an industry or market is to accommodate and support a new technology.

History has shown us that technologies don't emerge out of thin air. Those which fit into available infrastructures, have strong industry support, or can quickly construct complementary ecosystems stand a much better chance of ending up dominant. Technologies that require massive new investment in complementary assets, with insufficiently overwhelming value, are unlikely to achieve mainstream success.

4.5.1 - Complementary assets as an enabler of dominant designs

The presence of a proven ecosystem can be what sets a technology apart from a niche innovation to being an industry standard. Supporting complementary assets with the presence of new technology will aid in the adoption, maximize value, and reduce switching costs for potential adopters.

One of the most important categories of complementary assets is infrastructure. Take, for example, electric vehicles (EVs). Although EV technology itself has come a long way from its embryonic form, its mass adoption would not have been possible without the growth of charging infrastructure. Consumers need easy access to charging stations, battery supply chains, and maintenance networks to make EVs a viable alternative to traditional gasoline powered cars. Countries like China and Norway, which made early investments in widespread charging networks, had higher EV adoption rates than regions without this important ecosystem infrastructural backbone.

The same pattern is observed in the smartphone industry. Apple and Android smartphone supremacy was not just the result of their hardware quality or performance. What actually solidified their supremacy was the development of app ecosystems, developer tooling, and cloud based services that enhanced their value platforms. A smartphone without a robust app marketplace and service platform would be far less desirable to consumers.

Apart from infrastructure and digital platforms, service ecosystems are another fundamental form of complementary assets. In the case of aviation, the reason that some aircraft engine designs end up as the market leaders is not merely due to performance or fuel efficiency but also due to the fact that there are maintenance networks, spare parts, and pilot training programs by airlines that facilitate airlines to include the new technology in their fleet without any dislocation. This suggests that a novel airplane technology without an established maintenance and supply network could struggle to gain broad acceptance, even if it is technically better.

4.5.2 - The impact of supply chains and manufacturing ecosystems

Another essential element of ecosystem readiness is the supply chain and manufacturing ecosystem that supports a technology. Even if a new innovation is promising, if it requires complex or hard to source materials, or if there are not enough suppliers to meet production demands, it may never achieve dominance.

Take the example of RISC processors in data centers. Although RISC based architectures have clear energy efficiency advantages over traditional CISC processors, their adoption was sluggish at first due to supply chain limitations.

Take the example of RISC processors in data centers. Although RISC based architectures have clear energy efficiency advantages over traditional CISC processors, their adoption was sluggish at first due to supply chain limitations. The semiconductor ecosystem then was mostly CISC based processor optimized, which mean that manufacturers, software vendors, and server providers were significantly invested in the existing ecosystem.

4.5.3 - Complementary assets as a catalyst for dominant designs

Though technology innovation is crucial, it is always never enough by itself to ensure the success of a new technology. Access to complementary assets like charging points for electric cars, app ecosystems for cell phones, supply chains for semiconductors, or engine maintenance networks for jet engines does much to determine whether or not a technology becomes a dominant design.

Similarly, ecosystem maturity is just as crucial. Products that emerge in the market before mature industries that support them will not fare well, while products that can either integrate into existing infrastructure or develop their own ecosystem are far more likely to thrive.
It is crucial for innovators and strategists to understand the interplay of technology with ecosystem dynamics to predict which technologies will dominate. More critical than the performance of a technology for it to emerge as the standard in an industry is whether or not the world is ready to accommodate and expand adoption of that technology

4.6 - The DDPM – Dominant Design Prediction Matrix

Despite the diversity of sectors and technological maturity levels, these five dimensions emerged consistently as critical determinants in the race toward dominance.

This convergence led to the need for a structured, cross sectoral framework capable of evaluating competing technologies based on more than just their technical attributes. To this end, I developed the Dominant Design Prediction Matrix (DDPM): a comparative evaluation tool developed to anticipate which competing technologies are most likely to become dominant in a given industry. It operates by scoring each technological alternative across five critical dimensions: technological superiority, complementary assets, economic feasibility, regulatory and policy influence, and customer preferences. Each dimension reflects a key factor that shapes the adoption and diffusion of innovations beyond mere technical performance.

The DDPM provides a systematic framework that helps identify which technologies are most strategically positioned to become dominant. Each technological alternative is evaluated across the five aforementioned dimensions. To maintain consistency and allow comparability, I applied a 5 point scoring scale to each dimension:

- A score of 5 represents optimal alignment (e.g., a technology that is fully mature, supported by infrastructure, cost effective, politically incentivized, or strongly favored by users).
- A score of 1 indicates significant disadvantage or misalignment in that dimension (e.g., high cost, regulatory barriers, lack of ecosystem, or limited user appeal).
  Intermediate scores (2–4) reflect varying degrees of alignment or compromise.

To ensure the credibility and replicability of the DDPM, it is important to clearly define how the scores for each category are determined. The choice of evaluation methodology may depend on the availability of data, the maturity of the technology, and the context in which the framework is applied. The scoring can be carried out using one or more of the following approaches:

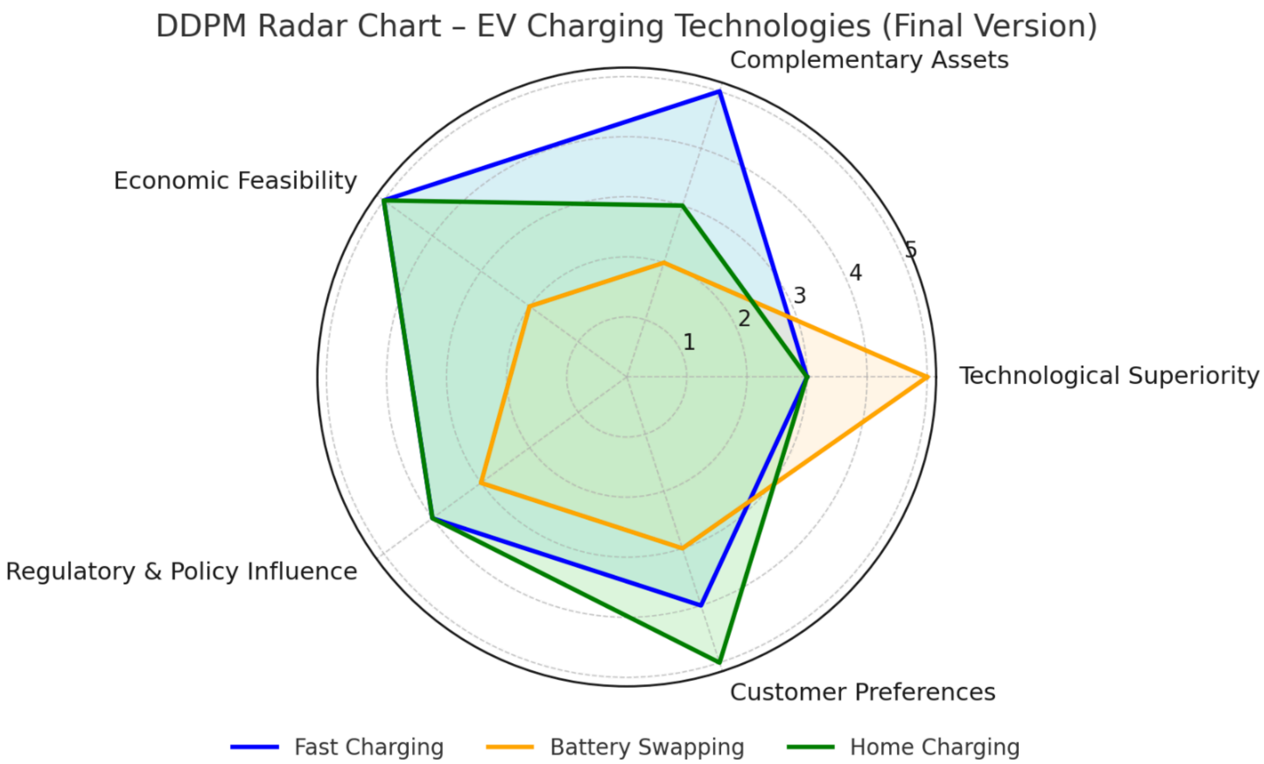
1. **Expert panel evaluation**
   Through workshops, focus groups, or structured interviews with subject matter experts (e.g., engineers, strategists, policy advisors), evaluators can assign scores to each sub-category based on their collective knowledge. Methods such as the *Delphi technique* can be used to reach consensus through iterative feedback rounds.
2. **Stakeholder surveys or questionnaires**
   Structured surveys can be used to collect scores or qualitative inputs from relevant stakeholders, such as consumers, regulators, or company decision-makers. Closed questions can directly correspond to DDPM categories.
3. **Document-based scoring**
   In cases where expert or stakeholder access is limited, scores can be derived from secondary sources such as academic papers, technical reports, policy documents, industry roadmaps, or market studies. This method relies on structured desk research to ensure traceability.
4. **Case-based benchmarking**
   When technologies are at a relatively advanced stage of diffusion, existing case studies or real-world deployments can be compared using predefined scoring rubrics. This is particularly useful for validating the scores assigned via more subjective methods.

However, often, an “Hybrid method” born by the combination of the above methods is most effective. For each category, certain evaluation methods may be more suitable than others depending on the context. In many cases, a combination of methods is recommended, for example, expert workshops can be guided by preliminary survey results or document analysis, while stakeholder interviews can serve to validate assumptions derived from secondary data.

In my analysis, I adopted a hybrid approach by combining the third and fourth methods, secondary data analysis and case-based benchmarking, leveraging the work of colleagues who had previously developed and examined the specific use cases.

These scores are then visualized using a radar chart, allowing for an immediate, intuitive understanding of each technology's strengths and weaknesses across the five strategic axes. The result is not a prediction tool in the deterministic sense, but rather a decision support framework that helps stakeholders, engineers, managers, policymakers, reason about technology trajectories and design dominance under uncertainty.

4.6.1 - EV Charging



Home Charging

- **Technological superiority (3):** While not the fastest method, home charging is technically mature and reliable for overnight use.
- **Complementary assets (3):** It leverages existing residential electrical infrastructure, though it is limited to users with private parking.
- **Economic feasibility (5):** It offers the most cost effective solution in the long term, with low installation and operational costs.
- **Regulatory & policy influence (4):** Often incentivized through installation subsidies, though it is less emphasized in national charging infrastructure plans.
- **Customer Preferences (4):** Highly appreciated by users due to its convenience, flexibility, and the possibility of charging during inactive hours.

Fast Charging

- **Technological superiority (3):** Not the most advanced, but technical progress has made it fast enough for mass adoption.
- **Complementary assets (5):** Fully compatible with the existing electric grid and easier to scale in both urban and highway contexts.
- **Economic feasibility (5):** More scalable and economically sustainable than battery swapping, with no need for spare batteries or complex systems.
- **Regulatory & policy influence (4):** Strongly supported by public initiatives promoting the expansion of fast charging networks.
- **Customer preferences (4):** Well received by users due to its accessibility, reasonable cost, and growing presence in key locations.

Battery Swapping

- **Technological superiority (5):** The fastest solution in terms of energy replenishment, offering near instant full charges.
- **Complementary assets (2):** Requires standardization across OEMs and significant investments in automated stations and spare batteries.
- **Economic feasibility (2):** Burdened by high infrastructure costs and the need to maintain costly battery inventories.
- **Regulatory & policy influence (3):** Present in some national strategies (e.g., China), but generally less supported than charging based systems.
- **Customer preferences (3):** Perceived as innovative but hindered by limited availability, unfamiliarity, and concerns about battery ownership.

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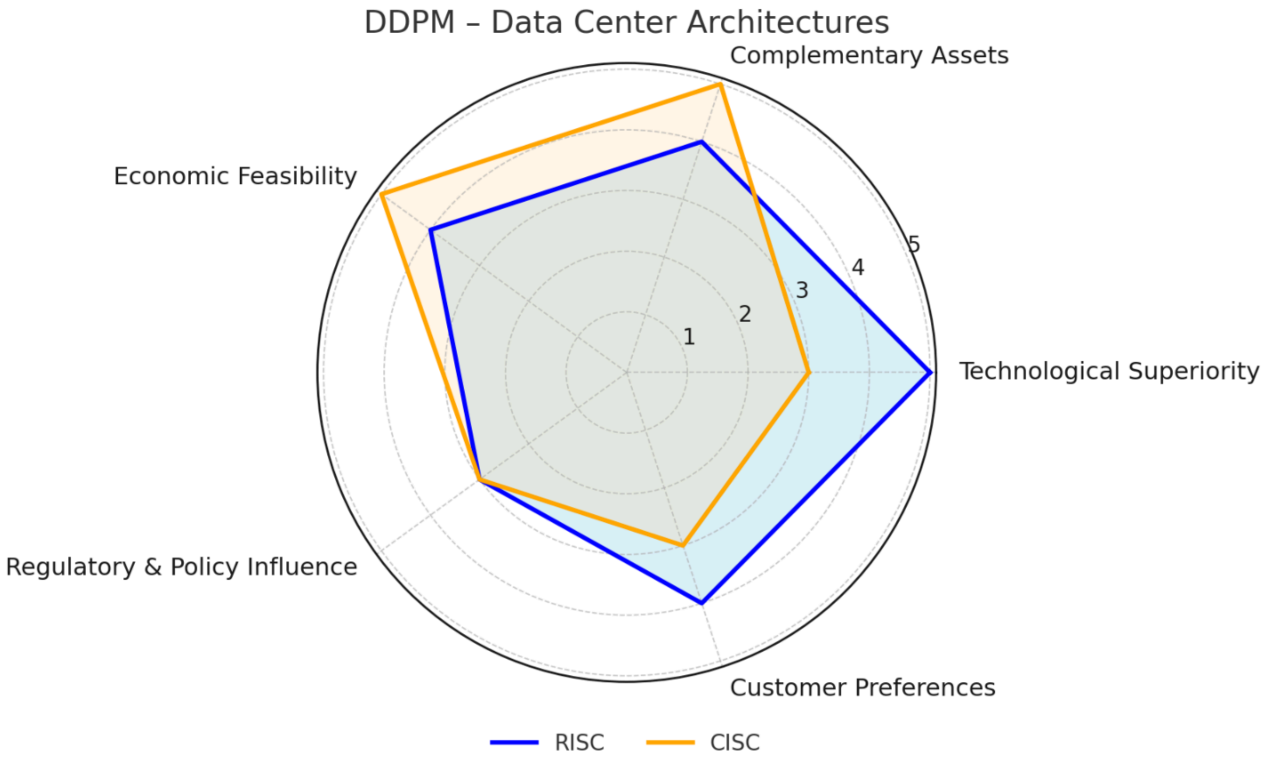
4.6.2 - Data centers



RISC

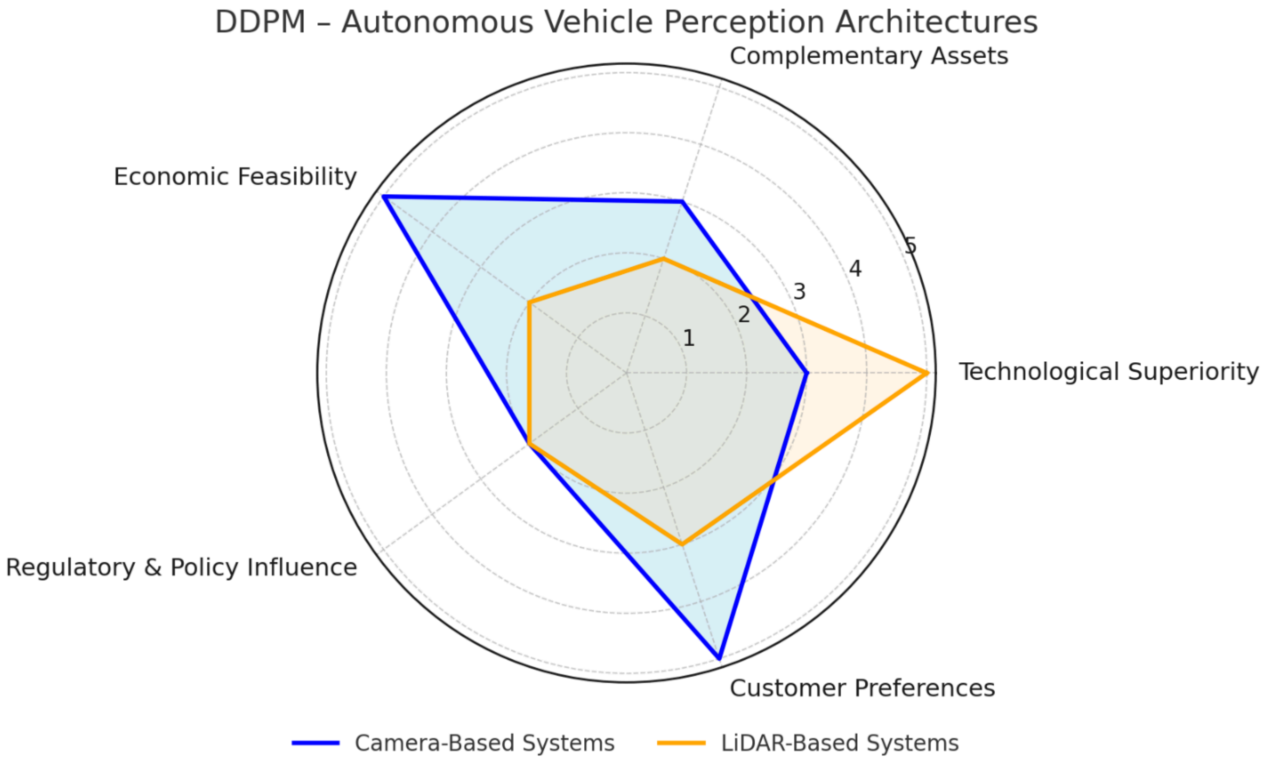
- **Technological superiority (4):** RISC processors offer significantly better energy efficiency and performance per watt, making them technologically superior for modern data center needs.
- **Complementary assets (3):** While not as deeply entrenched as CISC, RISC has gained support from cloud hyperscalers and open source communities, increasing its integration.
- **Economic feasibility (4):** Though it requires upfront investment in software adaptation, RISC is more cost efficient in the long term due to reduced energy usage and improved performance.
- **Regulatory & policy influence (3):** Although current regulations are neutral, emerging EU environmental policies are likely to favor RISC based solutions because of their lower power consumption.
- **Customer preferences (4):** Early adoption was hindered by switching costs, but customer demand for energy efficient and scalable solutions has led to increased RISC traction.

CISC

- **Technological superiority (3):** CISC architectures are mature but less efficient in terms of power and scalability when compared to RISC.
- **Complementary assets (5):** CISC benefits from a deeply established ecosystem, including hardware vendors, developer tools, and legacy application compatibility.
- **Economic feasibility (5):** For many enterprises, staying with CISC minimizes transition costs and protects existing investments, making it economically sound in the short term.

- **Regulatory & policy influence (3):** There is currently no specific regulation favoring CISC or RISC, though future environmental regulations may shift this balance.
- **Customer preferences (3):** Customers appreciate CISC for its stability and compatibility, but its energy inefficiency and aging performance model are gradually eroding its appeal.

4.6.3 - Autonomous vehicles



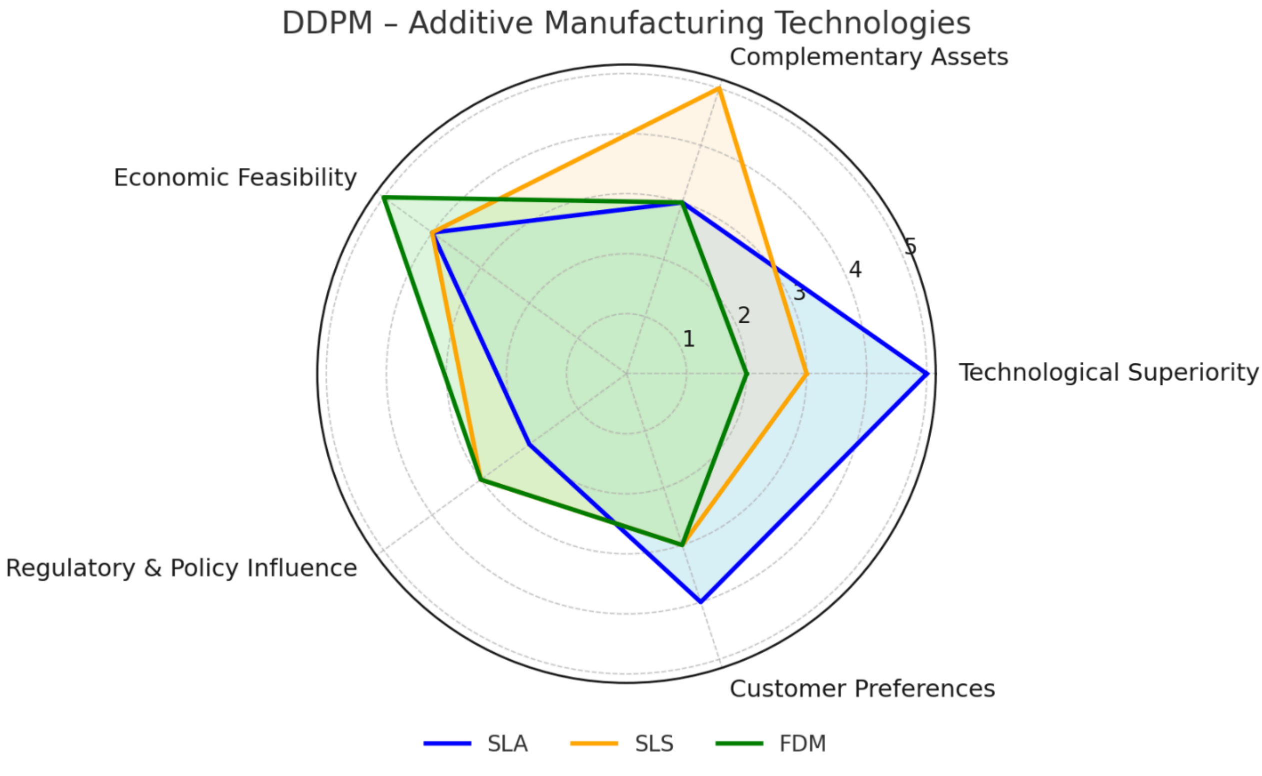
Camera based systems

- **Technological superiority (3):** While not as precise as LiDAR in spatial resolution, camera based systems provide sufficient accuracy for real world scenarios when combined with radar and software processing.
- **Complementary assets (3):** These systems integrate well with existing vehicle platforms and benefit from advances in ADAS technologies, though they require robust fusion algorithms to reach full autonomy.
- **Economic feasibility (5):** Camera based systems are significantly more cost effective than LiDAR, enabling broader deployment in consumer vehicles.
- **Regulatory & policy influence (2):** Lack of clear regulatory support for any specific architecture, combined with ongoing safety constraints, has slowed full scale adoption of both systems.
- **Customer preferences (5):** Consumers and manufacturers prefer affordable and scalable solutions; camera based platforms satisfy these demands more effectively.

LiDAR Based Systems

- **Technological superiority (5):** LiDAR delivers unparalleled depth perception and spatial accuracy, which is valuable in complex driving environments.
- **Complementary assets (2):** LiDAR integration typically requires custom vehicle architecture and additional computing infrastructure, making it harder to scale.
- **Economic feasibility (2):** High sensor and system costs limit LiDAR to premium vehicle segments and pilot programs.
- **Regulatory & policy influence (2):** LiDAR's potential is recognized, but no policies currently incentivize its adoption over other alternatives.
- **Customer preferences (3):** Despite technical benefits, the cost and limited availability of LiDAR systems reduce consumer demand and OEM interest.

4.6.4 - 3D Printing



SLA (Stereolithography)

- **Technological superiority (5):** SLA provides unmatched precision, surface detail, and adaptability across various high performance resins, making it a top choice in fields requiring fine tolerances such as healthcare and prototyping.
- **Complementary assets (3):** While historically limited, recent advances in post processing automation, material science, and large format SLA printers have strengthened its industrial ecosystem.

- **Economic feasibility (4):** Once cost prohibitive, SLA has become more economically viable due to falling resin prices, improved production speeds, and increased system automation.
- **Regulatory & policy influence (2):** SLA is favored in regulated sectors like medical and dental, especially due to its compatibility with sterilizable and biocompatible materials. Anticipated regulatory harmonization is likely to further boost adoption.
- **Customer preferences (4):** Customers in high precision industries increasingly prefer SLA for its aesthetic finish, dimensional accuracy, and material diversity making it a premium yet scalable option.

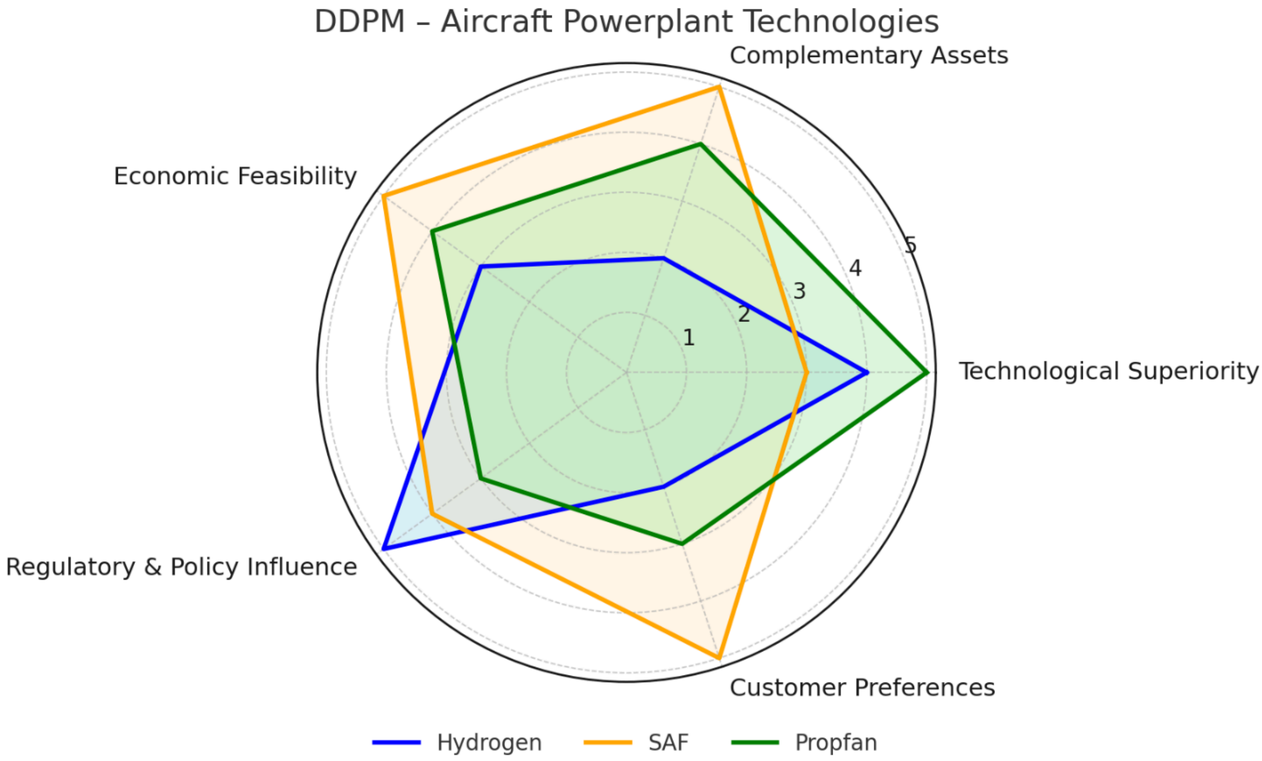
SLS (Selective Laser Sintering)

- **Technological superiority (3):** Offers high mechanical strength and is suitable for functional parts, though less detailed than SLA.
- **Complementary assets (5):** Benefits from a mature ecosystem of industrial machines, post processing systems, and wide material availability.
- **Economic feasibility (4):** More scalable for batch production but generally more expensive than FDM and increasingly challenged by the efficiency gains of SLA.
- **Regulatory & policy influence (3):** Commonly used in aerospace and automotive but less prominent in highly regulated industries.
- **Customer preferences (3):** Preferred in scenarios requiring mechanical functionality over visual quality, but less popular for applications demanding fine detail or surface aesthetics.

FDM (Fused Deposition Modeling)

- **Technological superiority (2):** FDM is less precise than SLA and SLS, offering limited resolution and finish quality, but is sufficient for basic prototyping and low complexity parts.
- **Complementary assets (3):** Benefits from a well-established consumer and prosumer ecosystem, including wide access to materials and equipment, but is less optimized for high end industrial workflows.
- **Economic feasibility (5):** The most affordable 3D printing method in terms of machine cost, material pricing, and operational simplicity.
- **Regulatory & policy influence (3):** Suitable for non-critical components but lacks the certifications and material standards required in regulated industries.
- **Customer preferences (3):** Preferred in education, makerspaces, and early stage prototyping for its ease of use and affordability, but not competitive for high precision or end use industrial applications.

4.6.5 - Aircraft powerplants



Hydrogen

- **Technological superiority (4):** Hydrogen offers exceptional energy density and emissions free operation, especially promising for long haul flights. However, storage and safety challenges remain significant barriers to deployment.
- **Complementary assets (2):** Unlike SAF, hydrogen requires entirely new distribution, storage, and refueling infrastructure, along with redesigned aircraft limiting near term feasibility.
- **Economic feasibility (3):** Hydrogen remains costly to produce, store, and deliver, and retrofitting or replacing aircraft involves significant capital investment.
- **Regulatory & policy influence (5):** Strong regulatory momentum and climate driven policies are accelerating investment and R&D in hydrogen aviation.
- **Customer preferences (2):** Airlines acknowledge hydrogen's sustainability potential but prefer SAF for its compatibility and lower transition burden in the near term.

SAF (Sustainable Aviation Fuel)

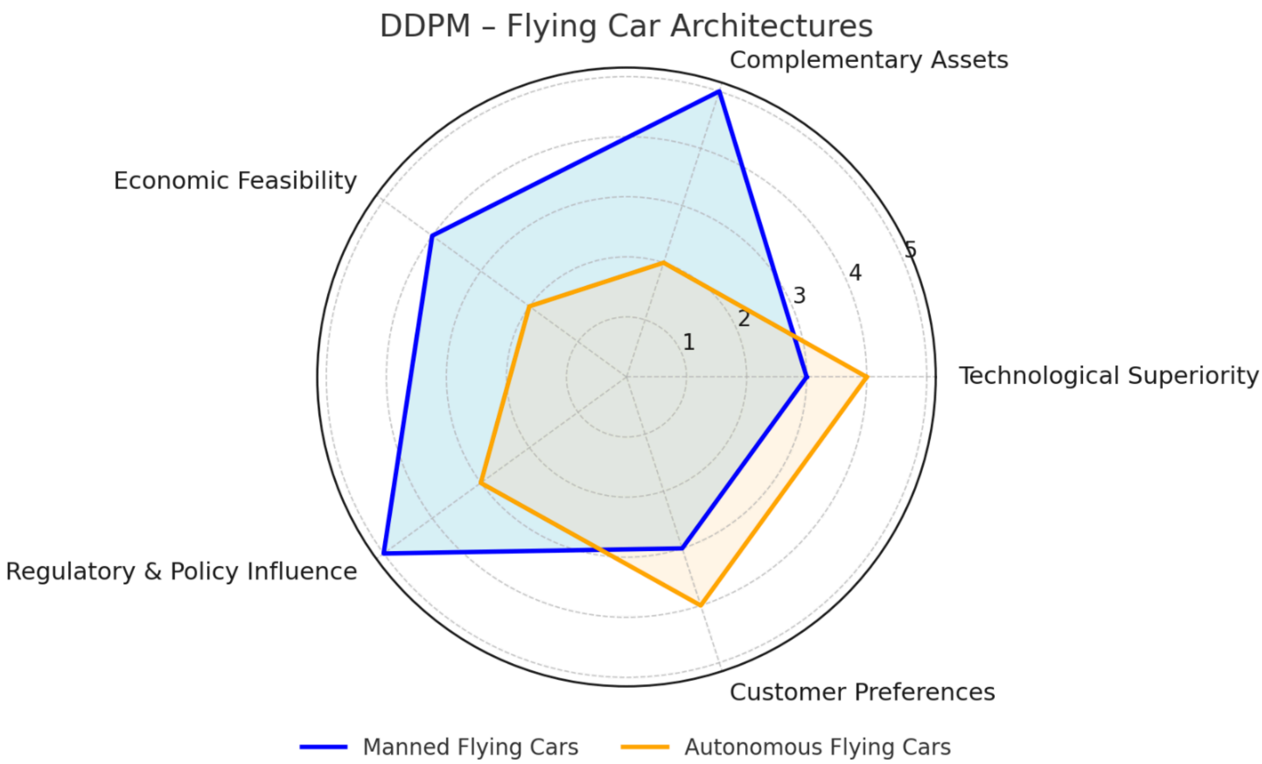
- **Technological superiority (3):** While not disruptive, SAF enables a significant reduction in emissions and can be used in existing aircraft engines with minimal modifications.
- **Complementary assets (5):** SAF can be distributed and used within the current aviation infrastructure, making adoption practical and immediate.
- **Economic feasibility (5):** Lower upfront cost compared to hydrogen and compatibility with existing airframes make SAF the most feasible short term solution.

- **Regulatory & policy influence (4):** Strong institutional support and incentives exist for SAF adoption, particularly in the EU and US.
- **Customer preferences (5):** Airlines strongly favor SAF because of its low transition cost and operational simplicity, making it the top choice for decarbonization in the near term.

Propfan

- **Technological superiority (5):** Propfans offer an excellent blend of turbofan and turboprop efficiency, delivering strong performance with reduced fuel consumption.
- **Complementary assets (4):** Can leverage existing engine and airframe integration with moderate adjustments, making them easier to introduce than hydrogen.
- **Economic feasibility (4):** Offers significant cost savings through fuel efficiency without requiring radical infrastructure overhauls.
- **Regulatory & policy influence (3):** While propfan is not a policy centerpiece, its fuel efficiency aligns with broader decarbonization goals.
- **Customer preferences (3):** Propfans are viewed as transitional — acceptable in niche or short haul applications but not yet widely favored due to concerns over noise and unproven long term operations.

4.6.6 - Flying cars



Manned Flying Cars

- **Technological superiority (3):** While not autonomous, manned flying cars benefit from existing aeronautical standards and piloting technologies, making them more reliable in the short term.
- **Complementary assets (5):** They can operate within the current aviation framework and do not require overhaul of air traffic systems or vehicle autonomy infrastructure.
- **Economic feasibility (4):** Easier to commercialize with current regulation, making them more economically viable in the near future.
- **Regulatory & policy influence (5):** Manned vehicles align with current aviation laws, allowing for more immediate deployment.
- **Customer preferences (3):** Users are more likely to trust human pilots during early market adoption, although automation could shift preferences over time.

Autonomous Flying Cars

- **Technological superiority (4):** Offers the long term benefit of full automation, though current reliability is not sufficient for unsupervised operation in all environments.
- **Complementary assets (2):** Requires the creation of a completely new ecosystem for air traffic control, autonomous navigation, and safety verification.
- **Economic feasibility (2):** Faces major barriers due to high development and certification costs.
- **Regulatory & policy influence (3):** Significant hurdles remain before full regulatory approval can be achieved, especially for urban environments.
- **Customer preferences (4):** Autonomy is appealing for convenience and future scalability, but current trust and perceived safety still favor piloted systems.

4.6.7 Deepening the DDPM with scenario planning: The case of RISC vs CISC in Data Centers

To illustrate the potential of the DDPM framework when enriched with foresight tools, this section presents a focused application on the case of RISC vs CISC processor architectures in the data center industry. While the initial DDPM scoring reflects current conditions, integrating scenario planning enables a broader understanding of how different futures may influence the emergence of a dominant design.

Base scenario: Current conditions

Under current market and regulatory conditions, the DDPM scoring reflects the trade-off between RISC's technological promise and CISC's entrenched market presence.

DDPM	RISC	CISC	Description
Technological superiority	4	3	RISC processors offer better energy efficiency and performance in the majority of the application but in few cases CISC it’s still better.

Complementary assets	3	5	CISC benefits from a deeply established ecosystem. RISC since it is newer is still building its ecosystem but at a very good pace.
Economic feasibility	4	5	Staying with CISC is cost-effective in the short term due to lower transition costs, but RISC is more advantageous in the long term thanks to its superior energy efficiency.
Regulatory & policy influence	3	3	There is currently no specific regulation favouring CISC or RISC, though future environmental regulations may shift this balance.
Customer preferences	4	3	Customers appreciate CISC for its stability and compatibility, but the demand for energy efficient and scalable solutions has led to increased RISC traction.

Alternative scenario: Policy driven shift

Considering a possible scenario in which governments introduce strict emission regulations specifically targeting the environmental footprint of data centers. These regulations establish mandatory caps on energy consumption and carbon emissions, compelling operators to adopt more energy efficient computing solutions. Alongside these restrictions, policymakers implement a range of financial incentives including tax breaks, grants, and investment subsidies to support and accelerate the transition toward greener infrastructures. This dual mechanism drastically changes the previous analysis leading to a forced change in the DDPM category scores and going to influence the emergence of one dominant design over the other.

In the new scenario three of the five categories will remain unchanged, but the other two will be modified as follows:

RISC

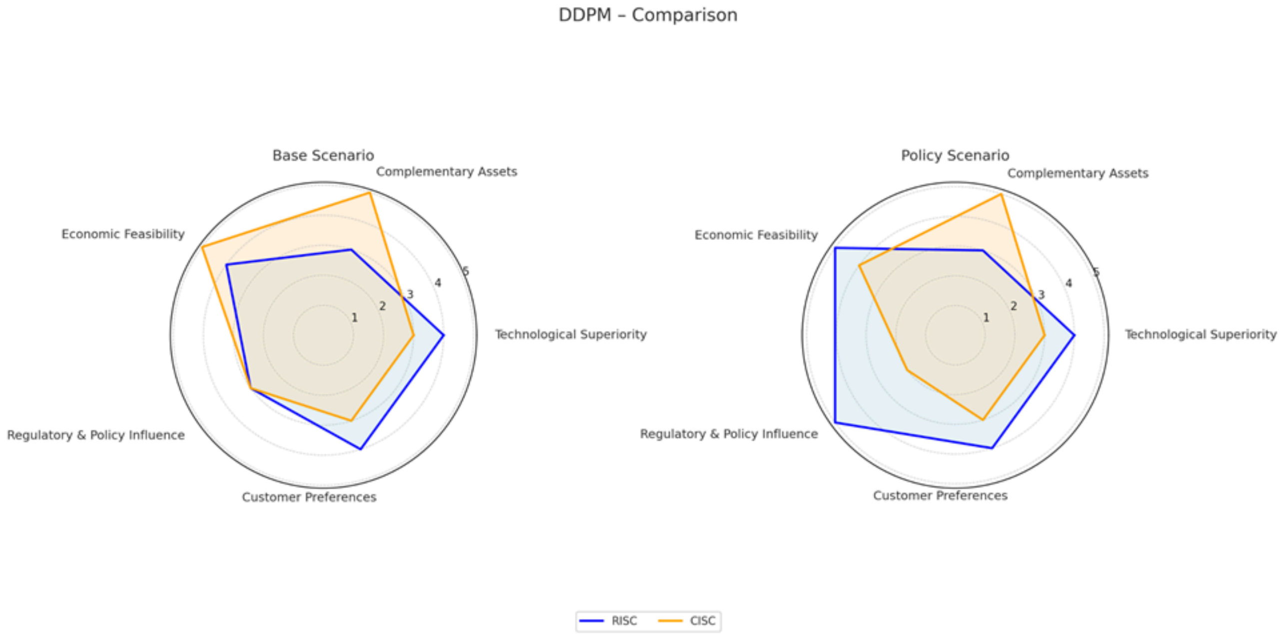
- **Economic feasibility (5)** Subsidies lower transition costs and RISC is more cost efficient in the long term due to reduced energy usage.
- **Regulatory & policy influence (5):** New regulations directly favor RISC's energy efficiency.

CISC

- **Economic feasibility (4**) Staying with CISC minimizes transition costs and preserves existing investments, but it entails higher energy consumption, which can lead to greater long-term economic costs.
- **Regulatory & policy influence (2):** Penalized by new emission standards.

Visual comparison: DDPM charts

The radar diagrams below illustrate the comparative shift in technology attractiveness between the base and policy scenarios:



Interpretative Insights

This example demonstrates how the DDPM framework, when used in conjunction with scenario planning, provides a dynamic and decision-relevant tool for evaluating emerging technologies. In the base scenario, CISC's dominance appears rational in particular on the short term. However, under a policy-driven shift, RISC becomes significantly more favourable.

Therefore, scenario planning enhances the DDPM not by replacing the structured evaluation, but by projecting how external forces may re-weight the same five evaluation dimensions, making it possible to anticipate rather than just react to dominant design transitions. Now a company can decide it's investment strategy, in fact, this insight enables firms to align R&D investments, form strategic partnerships, and prepare their operational capabilities in a way that maximizes alignment with the most likely dominant design. As a result, they not only reduce uncertainty but also strengthen their competitive advantage in the evolving market landscape.

4.6.8 Deepening the DDPM with subcategories analysis: The case of Manned vs Unmanned in Flying cars

Each of the five evaluation dimensions is broken down into distinct subcategories in order to improve the Dominant Design Prediction Matrix's (DDPM) transparency and robustness. These subcategories reduce ambiguity in interpretation, offer structured scoring guidance, and enable the method to be used in semi-quantitative analyses as well as qualitative expert-based evaluations. The final score is determined by giving each sub-category a value (ranging from 1 to 5) and then calculating the average, as opposed to depending on a single, general assessment for every dimension. This guarantees that the scoring accurately reflects the complex nature of evaluating technology in the real world.

Below is the breakdown of sub-categories for each DDPM dimension:

Technological Superiority

- **Performance metrics:** This subcategory evaluates how the technology performs along critical dimensions such as speed, accuracy, energy efficiency, or coverage. Stronger performance in these metrics signals a competitive edge in fulfilling user and market needs.
- **Maturity of technology:** Refers to how advanced the technology is in terms of real-world validation, often measured through TRL (Technology Readiness Levels). A more mature solution is less risky and easier to commercialize.
- **Scalability potential:** Focuses on the ability of the technology to expand from pilot projects to large-scale adoption. A scalable technology is one that maintains efficiency and cost-effectiveness when production and deployment increase.
- **Adaptability:** Captures how easily the technology can be adapted to multiple contexts or integrated with evolving use cases. Flexible technologies are more resilient to market and environmental changes.

Complementary Assets

- **Infrastructure availability:** Assesses whether the physical and digital infrastructure required for deployment already exists or must be created from scratch. Higher availability lowers adoption barriers.
- **Supply chain maturity:** Considers the readiness of suppliers, manufacturers, and distributors to sustain reliable production and delivery. Mature supply chains minimize bottlenecks and risk.
- **Ecosystem support:** Refers to the presence of partners, integrators, or platforms that enhance the technology's value proposition. Ecosystem backing accelerates adoption through network effects.
- **Ease of integration:** Evaluates how well the technology fits with legacy systems, standards, or operational practices. Technologies that integrate smoothly encounter fewer barriers to adoption.

Economic Feasibility

- **Production cost per unit:** Examines the direct cost of manufacturing or delivering the technology at current volumes. Low unit costs increase competitiveness.
- **Implementation cost:** Refers to additional expenditures needed to deploy the technology, such as training, installation, or adaptation. Lower implementation costs reduce customer resistance.
- **Cost trajectory:** Analyzes whether the technology is expected to become cheaper over time due to scale economies or technological improvements. A favorable trajectory enhances long-term adoption prospects.
- **Business model alignment:** Measures how well the technology fits existing industry structures and monetization mechanisms. Misaligned business models can hinder even technically superior solutions.

Regulatory & Policy Influence

- **Compliance readiness:** Evaluates whether the technology already meets current legal requirements, certifications, and technical standards. Early compliance reduces delays and costs.
- **Policy incentives/barriers:** Considers subsidies, mandates, or restrictions that can either accelerate or slow adoption. Supportive policies often make the difference between feasibility and stagnation.
- **Standardization efforts:** Looks at whether the technology is included in national or international frameworks that promote interoperability and trust. Standardization tends to drive mass adoption.
- **Alignment with societal goals:** Reflects how well the technology supports public priorities such as environmental sustainability, safety, or digital sovereignty. Alignment increases legitimacy and long-term backing.

Customer Preferences

- **Perceived value:** Captures the extent to which users see the technology as useful, convenient, or offering unique functionality. Strong perceived value accelerates adoption.
- **Adoption willingness:** Refers to the readiness of target users to change existing habits, workflows, or systems. High willingness reduces resistance.
- **Cost-benefit perception:** Measures whether users believe the benefits of adoption outweigh the financial and operational sacrifices required. A favorable ratio increases uptake.
- **User feedback:** Considers input from surveys, pilots, or early adopters that indicate satisfaction and highlight strengths or weaknesses. Feedback ensures market fit and validates assumptions.

To illustrate this method, the following table presents a worked-out example of how the subcategory evaluation is applied to the case of Flying Cars, comparing manned and autonomous alternatives.

Manned Flying Cars

Technological Superiority
• **Performance metrics (3):** Piloted vehicles rely on proven avionics and human decision-making, delivering reliable safety and operational performance.
• **Maturity (3):** Builds directly on existing aviation systems and regulations, so it is highly validated.
• **Scalability (3):** Expansion is possible, but constrained by training needs for pilots and infrastructure.
• **Flexibility (4):** Human pilots can adapt in real time to changing environments, giving greater operational resilience.

Complementary Assets
• **Infrastructure availability (5):** Integrates seamlessly into today's air traffic systems and airports.
• **Supply chain maturity (4):** Supported by an established aviation supply chain (manufacturers, maintenance).
• **Ecosystem support (5):** Training and certification institutions already exist to support operations.
• **Ease of integration (5):** Piloted cars align with existing rules, requiring minimal systemic change.

Economic Feasibility
• **Production cost (4):** Leverages existing aviation manufacturing processes, keeping unit costs manageable.
• **Implementation cost (4):** Training and adaptation costs exist but are not prohibitive.
• **Cost trajectory (4):** Costs are expected to stabilize and slightly decrease with scale.

• **Business model alignment (5):** Perfectly aligned with existing aviation models, including regulation and insurance.

Regulatory & Policy Influence
• **Compliance readiness (5):** Fits neatly into today's regulations for piloted aviation.
• **Policy incentives (5):** Supported as a safe, controlled innovation path.
• **Standardization efforts (4):** Aviation standards can be directly extended to flying cars.
• **Alignment with societal goals (4):** Incremental innovation is perceived as safer and more manageable for society.

Customer Preferences
• **Perceived value (4):** Seen as trustworthy because a pilot is in control.
• **Adoption willingness (4):** Customers are more willing to try a familiar, human-operated system.
• **Cost-benefit perception (4):** Balance between cost and benefits is positive compared to alternatives.
• **User feedback (4):** Early trials indicate enthusiasm and trust in piloted systems.

Autonomous Flying Cars

Technological Superiority
• **Performance metrics (5):** Autonomous systems can achieve strong precision, but reliability under unexpected conditions remains insufficient.
• **Maturity (2):** Most are still experimental and far from regulatory acceptance.
• **Scalability (3):** In theory scalable with AI, but depends on breakthroughs in autonomy and air traffic management.
• **Flexibility (3):** Algorithms are less capable of managing unforeseen events compared to humans.

Complementary Assets

• **Infrastructure availability (2):** Would require new digital air traffic management systems to safely operate.
• **Supply chain maturity (3):** Hardware is available but integration with AI and safety systems is immature.
• **Ecosystem support (2):** Few institutions or standards are ready to support large-scale autonomous flight.
• **Ease of integration (2):** No compatibility with today's systems; a new framework is required.

Economic Feasibility
• **Production cost (2):** Expensive sensors and AI raise unit costs significantly.
• **Implementation cost (2):** Requires massive investments in control systems and infrastructure.
• **Cost trajectory (3):** Costs could fall with scale, but only in the long term.
• **Business model alignment (2):** Misaligned with current aviation practices, requiring entirely new models.

Regulatory & Policy Influence
• **Compliance readiness (1):** No regulatory approval or framework currently exists.
• **Policy incentives (1):** Governments block full deployment due to safety concerns.
• **Standardization efforts (2):** No international or national standards available.
• **Alignment with societal goals (4):** Attractive for the future, but near-term risks make it socially less acceptable.

Regulatory & Policy Influence
• **Compliance readiness (1):** No regulatory approval or framework currently exists.
• **Policy incentives (1):** Governments block full deployment due to safety concerns.
• **Standardization efforts (2):** No international or national standards available.

• **Alignment with societal goals (4):** Attractive for the future, but near-term risks make it socially less acceptable.

Manned	**Average (Subcategories)**	**Previous Grade**
Technological superiority	3.25	3
Complementary assets	4.75	5
Economic feasibility	4.25	4
Regulatory & policy influence	3.25	3
Customer preferences	4	4

Unmanned	**Average (Subcategories)**	**Previous Grade**
Technological superiority	3.25	4
Complementary assets	2.25	2
Economic feasibility	2.25	2
Regulatory & policy influence	2.25	3
Customer preferences	2.75	4

The expanded DDPM framework's improved assessment of manned and unmanned flying cars shows how a more detailed approach can produce a more thorough and impartial understanding of technological trajectories. Regarding manned vehicles, the revised evaluation strengthens their position in terms of complementary assets (4.75) and economic viability while marginally diminishing their technological superiority. This demonstrates their comparative advantage as the best short- to medium-term choice. On the other hand, unmanned flying cars show a significant decline in a number of areas, most notably in customer preferences (2.75 compared to 4) and regulatory and policy influence (2.25 compared to 3). These findings demonstrate enduring obstacles related to user acceptance, regulatory ambiguity, and safety concerns.

All things considered, the comparison highlights the importance of including subcategories in the DDPM since it makes it possible to identify subtle trade-offs and prevents potential distortions brought on by oversimplified scoring. While the widespread adoption of unmanned solutions is likely to depend on longer-term technological, regulatory, and societal shifts, the findings indicate that manned flying cars may emerge as an intermediate dominant design.

CHAPTER 5 – Conclusion

Throughout this thesis, the goal has been to understand how dominant designs emerge across different industries and whether it's possible to anticipate their rise through a structured and replicable approach. To do so, we applied a methodology rooted in Technology Forecasting and Customer Focused Technology Planning (CFTP), looking across a range of diverse case studies.

5.1 - The Dominant Design Prediction Matrix (DDPM)

In light of these insights, this thesis proposes a model to support more structured and forward looking evaluations: the Dominant Design Prediction Matrix, or DDPM. The idea behind the DDPM is to move beyond anecdotal or retrospective reasoning and offer a tool that can be applied proactively to compare emerging technologies.

The DDPM revolves around five fundamental dimensions, each of which played a recurring role in our case studies:

1. **Technological superiority**: How well the technology performs relative to its competitors.
2. **Complementary assets**: The degree to which infrastructure, services, and platforms are ready to support its deployment.
3. **Economic feasibility**: How costly the technology is to adopt and operate, including switching costs.
4. **Regulatory & policy influence**: Whether the solution is compatible with the legal and policy environment, and if it enjoys support or faces barriers.
5. **Customer preferences**: The extent to which the technology resonates with what users want, need, or are willing to accept.

By rating each option across these dimensions typically on a scale from 1 to 5 we obtain a visual and comparative understanding of their strengths and weaknesses. This helps stakeholders grasp which technologies are not just technically impressive but also strategically positioned to succeed.

5.2 - Application across case studies

The application of the DDPM across a variety of industries revealed consistent dynamics in how dominant designs tend to emerge. First, no solution emerged as dominant purely on the basis of its technical merit. In every case, the interplay between customer preferences, ecosystem maturity, economic rationality, and regulatory conditions proved just as influential as raw performance.

Technologies that aligned moderately well across all five dimensions generally outperformed those that were superior in only one or two. For instance, a technically advanced but cost intensive solution with low ecosystem compatibility struggled to gain traction, whereas a “good enough” solution with strong integration and user familiarity often prevailed. This trend held regardless of whether the technology was in a physical product domain (like aircraft or 3D printing) or a system level infrastructure (like charging or sensing).

Another recurring pattern was the importance of timing: early mover advantages combined with ecosystem alignment frequently outweighed late stage performance gains. Path dependency and switching costs were especially critical in technologies with high upfront investment or legacy infrastructure. Finally, customer acceptance, often underappreciated in classical models, emerged as a decisive factor in several cases, reinforcing the need for demand side foresight during the fluid phase of technological development.

5.3 - Limitations

Of course, the DDPM is not without its limitations. Its current structure relies on a combination of qualitative judgment and semi quantitative scoring, which introduces a degree of subjectivity. Additionally, the model does not explicitly account for external shocks, geopolitical disruptions, or rapid shifts in consumer sentiment. The evolution of dominant designs over time a dynamic and nonlinear process is also not directly modeled in this version of the framework.

5.4 – Final remarks

The comparative lens offered by the DDPM has allowed for a structured reflection on a central insight: dominant designs are not simply the product of superior technologies, but the result of multi-dimensional alignment within a dynamic and often unpredictable environment. The emergence of a dominant design reflects not just engineering performance, but also institutional endorsement, economic logic, ecosystem maturity, and user perception.

By bringing these dimensions into a single evaluation framework, the DDPM doesn't attempt to predict outcomes with certainty, but instead provides a repeatable method for assessing trade-offs and strategic fit. Its main utility lies in making these trade-offs explicit, encouraging more holistic innovation planning, and revealing tensions between short term viability and long term potential.

While every industry has its specificities, the consistency of patterns across case studies suggests that the DDPM can serve as a useful comparative tool for early stage technology assessment. Its value is not prescriptive, but diagnostic: it helps innovators, investors, and policymakers ask better questions about where a technology is heading and why.

Looking back at the challenges outlined in Chapter 2 particularly the need for a more integrative and predictive approach to dominant design emergence the Dominant Design Prediction Matrix (DDPM) represents a potential step forward. It broadens the scope of evaluation beyond technological performance, incorporating external variables such as customer preferences, economic feasibility, and policy influence. In this sense, it addresses some of the key limitations of traditional models like Abernathy-Utterback and Suarez's framework, especially when applied during the fluid phase of technological development.

That said, I remain cautious about the framework's practical applicability in real world forecasting. While the DDPM offers structure and comparative clarity, its value largely depends on the quality of available data, the expertise of those assigning scores, and the evolving context of each industry. The framework should therefore be considered more of a support tool for strategic discussion than a deterministic model. Its greatest contribution may lie not in predicting the future with certainty, but in helping stakeholders frame better questions, compare alternatives more transparently, and recognize the multidimensional nature of technological competition.

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