Digital Transformation, Ecosystem Design, and Platform Strategy: An IIoT Perspective.

by

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Abstract

Platform business model and digital transformation are two hot trends that have seen many companies launch their own digital platforms. There are many new companies along with established incumbent companies adopting the platform model. They face common challenges in deciding the use cases, partners, governance, markets, positioning, and timing. I review the platform literature and overview the IIoT technology landscape. GE and Siemens are two established companies that adopted contrasting strategies for their IIoT platform. Siemens' MindSphere is considered a success, but GE Digital, even though it spent more than $4 billion and coined the term 'Industrial Internet', has struggled. I draw lessons for digital platforms by comparing their approaches and results. I extend the learnings further by developing a general approach using network graph and input-output model for bottleneck market selection and market ecosystem design by converging the industry and product platform approaches. I model the selection of additional markets as sides for launch as an optimization problem. Finally, I provide a decision framework for positioning of the platform during market launch. The work done aids platform owners in deciding their strategy and resulting scope of the platform.

Thesis Supervisor: Dr. Michael A. Cusumano
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1. Introduction

The essence of today's zeitgeist is increased collaboration and interconnectedness facilitated by digital technologies resulting from the following trends that dominate the business landscape of the world:

1. Rapid pace of technology change [1]
2. Increased system complexity and need for specialization [2]
3. Increased availability of data, cheap processing power, and AI.

Multiple studies have shown that the pace of technology spread has increased over the years. Figure 1 shows the consumption spread for various widely adopted technologies over the years [1]. We are living in an era of increasing complexity and interdependence. The complexity and the resultant need for specialization has made it difficult for an entity to operate in isolation.

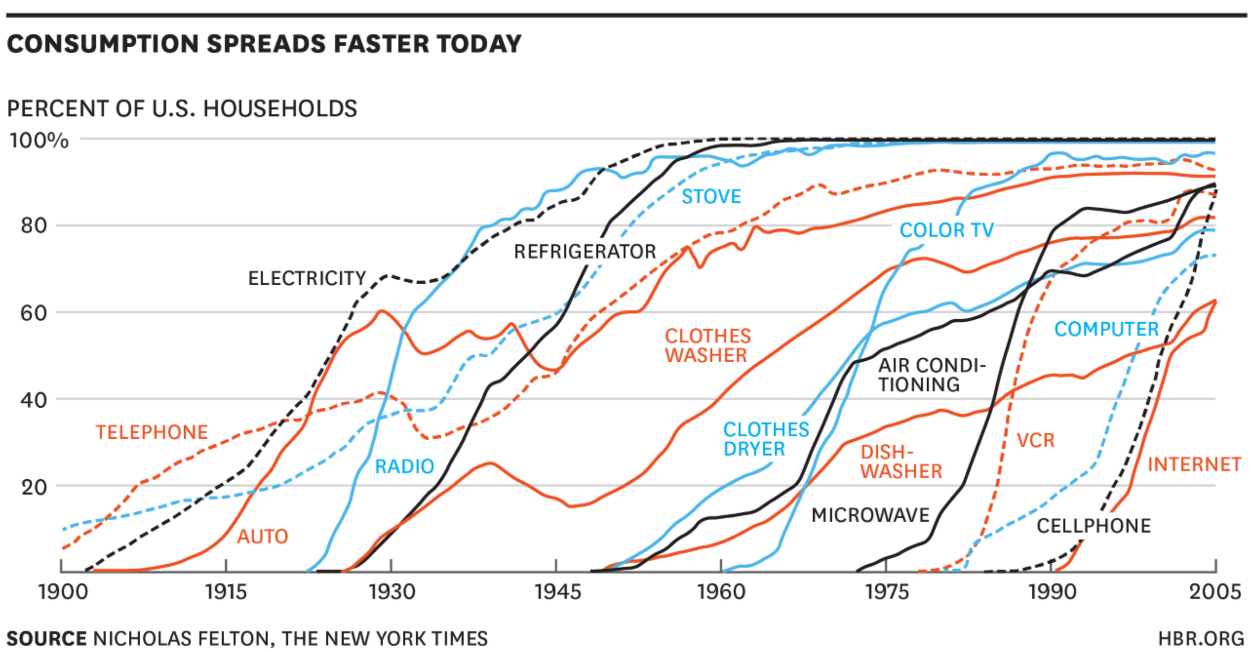

Figure 1 Pace of Consumption Spread of Various Widely Used Technologies. [1]

With the faster pace of technology changes the complexity of products, services, and business models as defined by multiplicity, interconnectedness, and heterogeneity has increased [2] [3]. The increase in complexity has resulted in increased collaboration as seen by the growth of 1000+ author papers in recent years [4]. Increased collaboration is necessary as a single person or company is not able to fulfill the resource demands due to the increased specialization needs. Increased collaboration is not necessarily a defensive response. The value of a network increases faster with increase as the number of participants in it as per Metcalfe's law and can result in market dominating results [5]. Thus, increased collaboration is here to stay and can be used both for market defense as well as market dominance purpose.

Similarly, improvements in sensor technology, internet connectivity, computation processing power, and progress in artificial intelligence technology has increased the availability of data and the ability to analyze and draw insights from them. Data is the new oil in today's world [6].

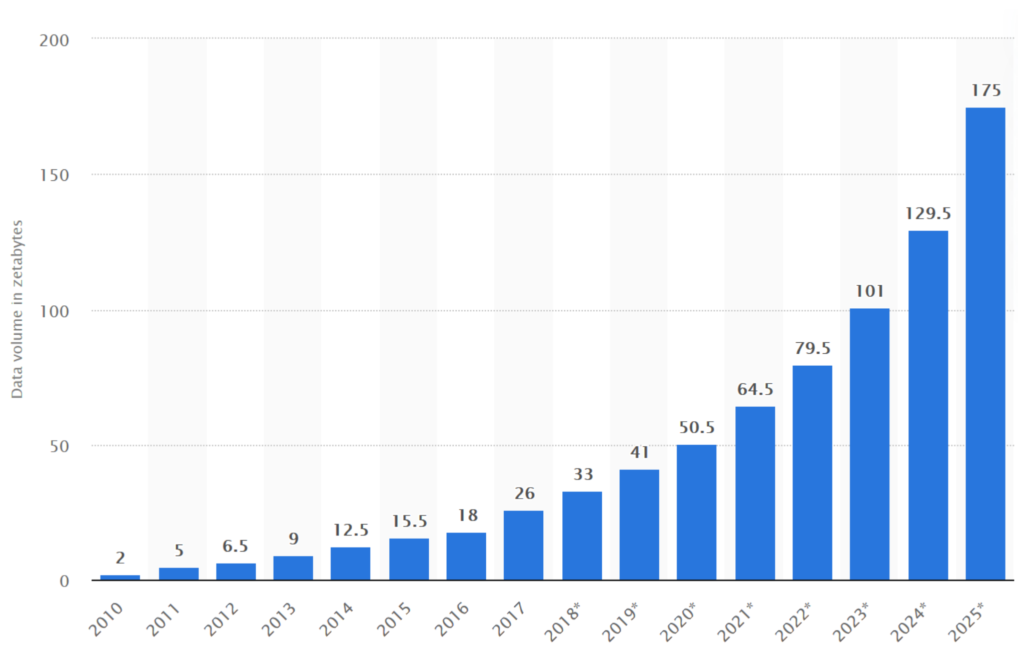

Figure 2 Annual worldwide data generation per year. [6]

Increasingly, in the business world the above trends manifest themselves in terms of collaboration centered around core digital technology platforms specialized in the market segment in which they operate. Industrial Internet of Things (IIoT) platforms and ecosystems are a prominent example of such collaboration. The three trends and the resultant digital technology assisted interconnectedness discussed in the previous chapter manifest themselves in Industrial Internet of Things (IIoT) platforms and their ecosystems.

1.1 Motivation and Objectives

IIoT is the backbone and one of the most important of the nine core technologies identified as technologies of the future in Industry 4.0 [8]. IoT is a fast-growing market with a compound annual growth rate of 23% between 2018 to 2023 [7]. The market is projected to grow to $141 Billion USD in 2023. IIoT, platforms, and ecosystems have become increasingly prevalent over the recent years.

It has been fascinating to observe the growth of platforms such as Uber, Airbnb, Amazon, Android, iOS in the past few years along with skyrocketing valuations. The author has been intrigued by their business models that achieved the high market valuations within short periods of time and at a fraction of cost of the industry incumbents that they displaced. Having previously worked in automotive, energy, and manufacturing industry with a side hobby in Raspberry Pi and IoT projects, IIoT platforms and ecosystems were a natural topic of exploration for this work.

This study aims to understand important success factors and approaches to build platforms and ecosystems that companies should consider for growing in the IIoT world, in particular, and in markets, in general. The author aims to learn important lessons from the study to guide his future career in business.

1.2 Problem, Scope, and Research Methodology

1.2.1 Problem

Many leading companies have jumped on the IIoT platform bandwagon, but only few appear to be successful [93]. There are multiple fascinating aspects of IIoT platform ecosystems – IIoT technologies and future trends, visualization and value network analysis, ecosystem metrics, competition and coopetition among platform companies and ecosystem as well as among different platforms, value creation and value sharing, ecosystem dynamics and growth, partner selection and ecosystem design, strategy design using real options, platform and ecosystem strategy implementation, business models, incentive and value creation, organizational and governance models, ecosystem optimization, etc.

This work aims to study some of the leading IIoT platforms to compare platform and ecosystem strategies of these companies for the purpose of identifying successful growth approaches. More specifically the author aims to answer the following questions-

1. Why should an industrial company become an IIoT platform?
2. What are the ecosystem important design, governance, and business model related considerations for success for a company trying to build an ecosystem?
3. How should an aspiring ecosystem company select markets, partners, and go-to-market strategy?

1.2.2 Scope

The study will focus on GE Predix and Siemens Mindsphere. The study of these companies provides a comparison between industrial leaders such as GE and Siemens, conglomerates with long history and large revenue stream.

1.2.3 Research Methodology

As a first step, the study will review publications and articles that relate to platform thinking. The study will then use case study research method to analyze the case of GE and compare the findings with those from another similar company, Siemens to draw lessons. This method of study is most appropriate do draw lessons from real-life examples. The study will use multiple articles, research papers, databases, market reports, and methodologies to analyze the data and draw general conclusions. The literature review and case study will be followed by use of the platform, marketing, network analysis, and optimization theory to propose a general decision guidance schema for platforms in the IIoT space, which could also be used by platforms in other areas.

2. Ecosystems, Platforms, and Platform Strategy

This chapter reviews the literature on platform thinking and gives an overview of important concepts such as, ecosystems, platforms architecture, governance, competition, drivers, and strategy, which it uses as a platform to build on further in the thesis.

2.1 Just one word: Platforms![1]

Ecosystems and platforms are becoming more and more pervasive with decreasing advantages of vertical integration with incremental innovation in technology industry according to the double helix model by Fine [85]. Platforms and their ecosystems consist of a group of companies or entities that coalesce around and are led by a central orchestrating platform company. Windows, Android, Uber, Amazon, etc. are few examples of platforms and ecosystems. Platforms provide a clear value proposition to the participants by providing reduced transaction costs and reduced cost of common platform infrastructure. Platform companies rely on economies of demand due to network effects and form an ecosystem of companies and/ or entities aligned towards a common or similar goal. Cusumano, Gawer, and Yoffie study Forbes 2000 companies and show that despite comparable revenues to other firms in the same industries, platform companies have about half the number of employees, much higher operating

[1] A spin on the famous movie dialogue from the movie 'The Graduate', https://www.youtube.com/watch?v=PSxihhBzCjk

profits, and much higher market values as well as higher ratios of market value to sales [47].

This superior performance exhibited by platforms and ecosystem companies is due to shifting of the focus from internal value creation to external value creation by inverting the firm. This focus shift allows the firms to-

1. Scale more efficiently
2. Bring products to market at a faster pace
3. Distribute the costs of research and development
4. Unlock new sources of value creation and supply
5. Create feedback loops by connecting users
6. Reduce risk
7. Improve resilience and agility in responding to changes in external environment

2.2 Ecosystems and Platforms

Businesses have traditionally used pipeline models with a producer of goods that are distributed by a distribution and sales pipeline. Another architecture that is being increasingly adopted is based on the ecosystem model. Ecosystems consist of a group of entities in a mutually beneficial relationship. Business ecosystems are increasingly becoming popular with the number of publications with the term 'ecosystem' in title increasing at a rapid pace.

Ecosystem is defined as:

An ecosystem is a set of actors with varying degrees of multilateral, non-generic complementarities that are not fully hierarchically controlled [9].

Jacobides, et.al describe unique or supermodular complementarities as required characteristics of ecosystem-based collaboration that have a specific structure of relationships and alignment to create value [9,10]. Pidun et.al list following distinguishing characteristics of ecosystems [10]:

1 Modularity
2 Customization
3 Multilateralism
4 Coordination

Ecosystems follow a hub and spoke architecture, where a central player guides the evolution of ecosystems. Figure 3 shows the modularity and coordination required for the different type of systems.

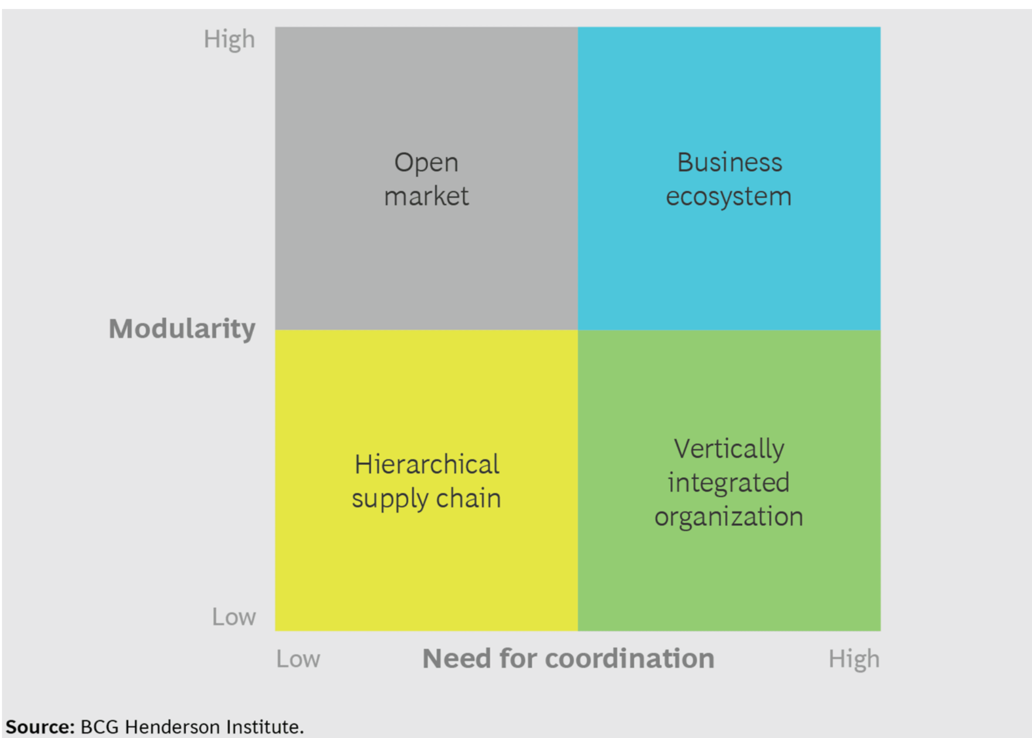

Figure 3 Comparison of systems based on modularity and required coordination. [9]

Ecosystems consist of interdependent entities that create and share value. Thus, ecosystems differ from hierarchy-based supply chain systems and market-based systems as seen in Figure 4 in how they interact and connect with customers. As user generated innovation is becoming increasingly common, the consumers are increasingly being considered as part of ecosystems. Consumers share inputs or suggestions with the companies and in return get the benefit of improved or discounted products. Chinese smartphone manufacturer Xiaomi is an example of company using consumer feedback on a regular basis as a differentiator [11].

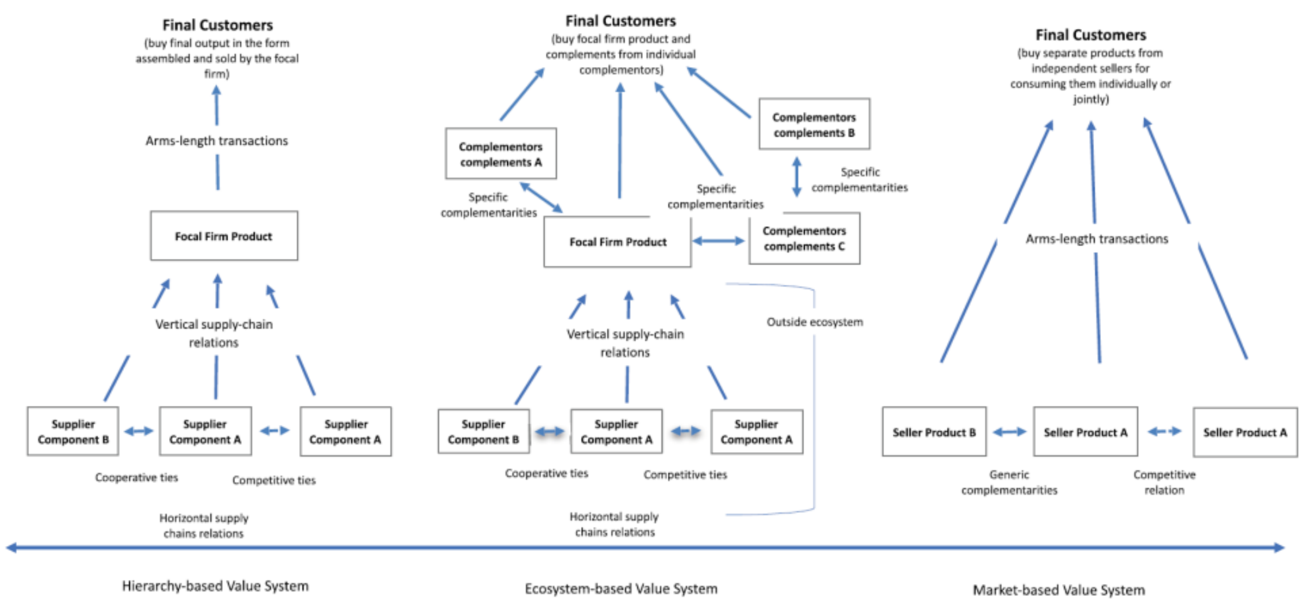

Figure 4 Comparison of supply chain, ecosystems, and market-based systems. [9]

Figure 5 Ecosystem classification based on complexity and orchestration. [11]

The ecosystems deliver a value proposition for the customer based on complementary competencies and resources. The individual agendas and goals of the ecosystem partners are orchestrated by a focus firm called platform. The ecosystem partners also need to modulate their goals, competencies, and resources in relationship with other partners. The internal arrangement and relationships between the actors in an ecosystem affect the performance of the ecosystem. Ecosystems can be characterized based on complexity and orchestration as shown in Figure 5.

Cusumano, Gawer, and Yoffie use the actor centric view of ecosystems and define a platform as those- *that bring together individuals and organizations so they can innovate or interact in ways not otherwise possible, with the potential for nonlinear increases in utility and value* [16]. They differentiate the platforms as transaction platforms, innovation platforms, and hybrid platforms based on the primary function of the platform.

[2]Innovation platforms are described as- *These platforms usually consist of common technological building blocks that the owner and ecosystem partners can share in order to create new complementary products and services, such as smartphone apps or digital content such as from Apple iTunes or Netflix. By "complementary," we mean that these innovations add functionality or access to assets that make the platform increasingly useful.*

[3]Transaction platforms are described as- *These platforms are largely intermediaries or online marketplaces that make it possible for people and organizations to share information or to buy, sell, or access a variety of goods and services.*

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[2] Cusumano, Michael A.; Gawer, Annabelle; Yoffie, David B.. The Business of Platforms (p. 19). HarperBusiness. Kindle Edition.

[3] Cusumano, Michael A.; Gawer, Annabelle; Yoffie, David B.. The Business of Platforms (p. 20). HarperBusiness. Kindle Edition.

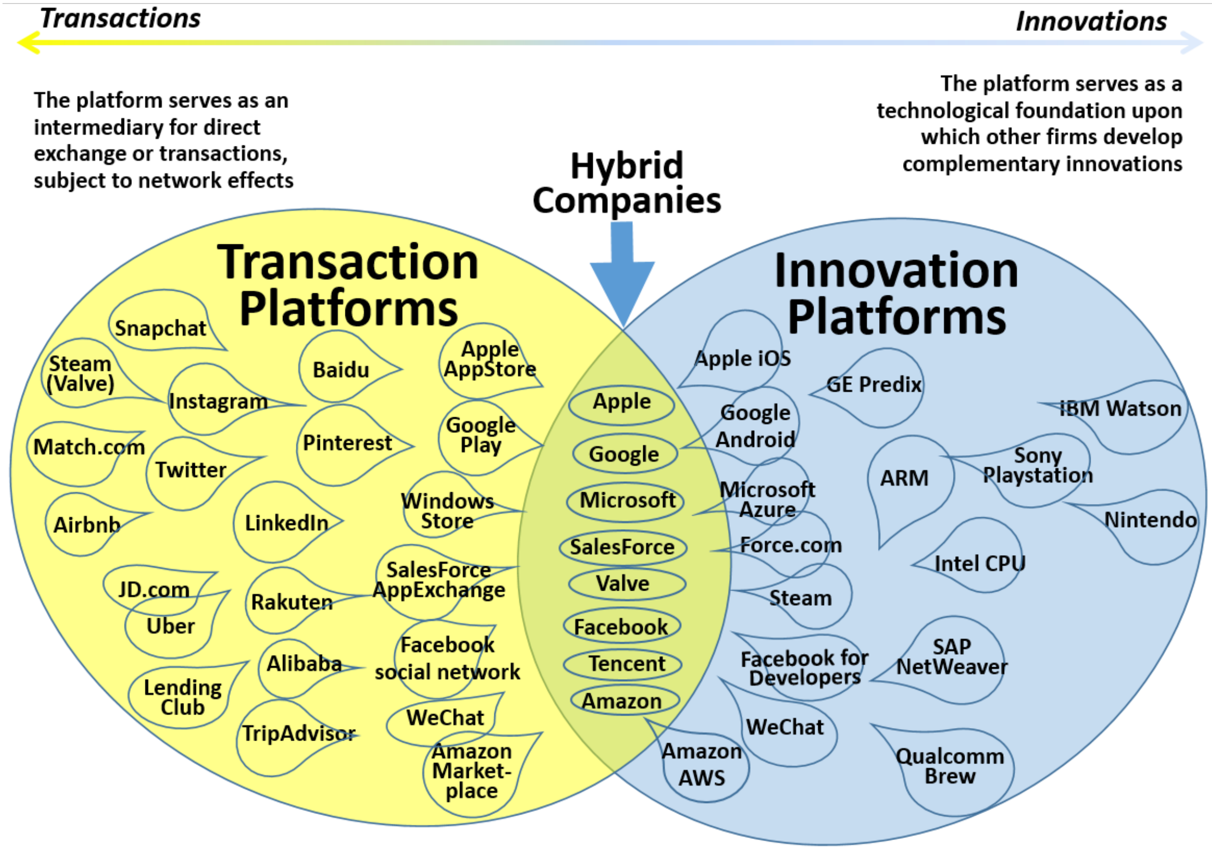

Figure 6 Classification of Platforms. [16]

2.2.1 Ecosystem Architecture

Ecosystems are designed such that the architecture influences the function, performance, and evolution of the ecosystem. The ecosystem architecture defines mechanisms of value creation and value capture. The 'ecosystem-as-structure' approach takes an activity-centric view of interdependent activities for realization of value proposition as opposed to the 'ecosystem-as-affiliation' approach that defines an ecosystem as an association of actors, their relationships, and their interdependence [44]. Adner defines an ecosystem as- *the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize* [44].

Adner considers value proposition at the center of the ecosystem design so that each new value proposition and the associated use case is associated with its own ecosystem. This view becomes cumbersome to use in the case of large corporations or platforms with multiple use cases, markets, and partners.

Moore, who was the initial user of business as ecosystem view, defines the business ecosystem as- *An economic community supported by a foundation of interacting organizations and individuals – the organisms of the business world* [45]*. This economic community produces goods and services of value to customers, who are themselves members of the ecosystem. The member organism also includes suppliers, lead producers, competitors, and other stakeholders. Over time, they coevolve their capabilities and roles, and tend to align themselves with the direction set by one or more central companies. Those companies holding leadership roles may change over time, but the function of ecosystem leader is valued by the community because it enables members to move toward shared visions to align their investments, and to find mutually supportive roles.*

Iansiti and Levien describe business networks as- *ecosystems, organized around a keystone species, and characterized by a large number of loosely interconnected participants who depend on each other for their mutual effectiveness and survival* [96] [97]. Baldwin and Woodard define platform architecture as modularization that divides the ecosystem into two sets of components- a stable set and a variable set that is complementary to the stable set and is allowed or encouraged to evolve [98]. The platforms take a 'hub and spoke' form with the peripheral firm connected to the central platform via shared or open-source technologies and/ or standards [9]. The platform partners not only generate complementary innovation, but also gain access to the customer base of the platform.

Eisenmann, Parker, and Van Alstyne describe the roles associated with the platform ecosystem. Demand-side platform users are the end users [55]. Supply-side platform users offer complements and build on top of the platform. Platform providers serve as the users' primary point of contact with the platform. Platform owners are responsible for controlling the property rights, setting the rules, and developing the technology.

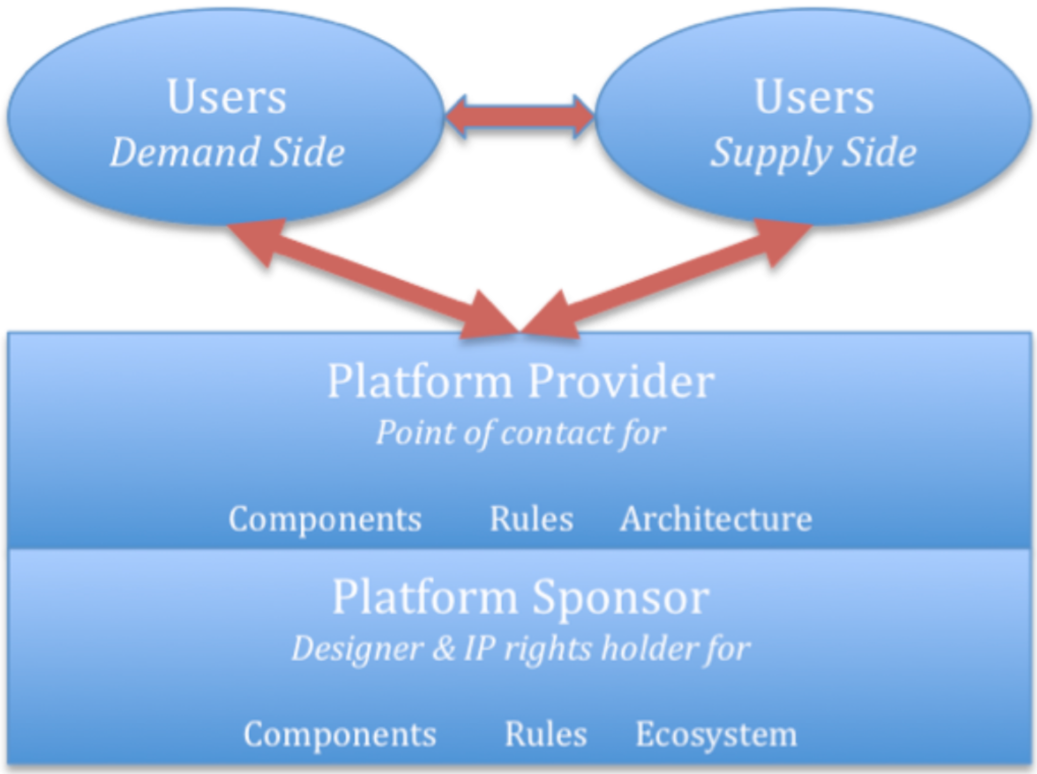

Figure 7 Various Roles in a Platform. [17]

2.2.2 Models and Frameworks

Gawer conceptualizes technological platforms as evolving organizations characterized by a coherent set of attributes- organizational form, interfaces, access capabilities, and governance -represented as inscribed in a continuum [94]. She uses the conceptualization to differentiate between internal, supply-chain, and industry platforms. Technological platforms are seen as- *evolving organizations or meta-organizations that: (1) federate and coordinate constitutive agents who can innovate and compete; (2) create value by generating and harnessing economies of scope in supply or/and in demand; and (3) entail a technological architecture that is modular and composed of a core and a periphery* [94].

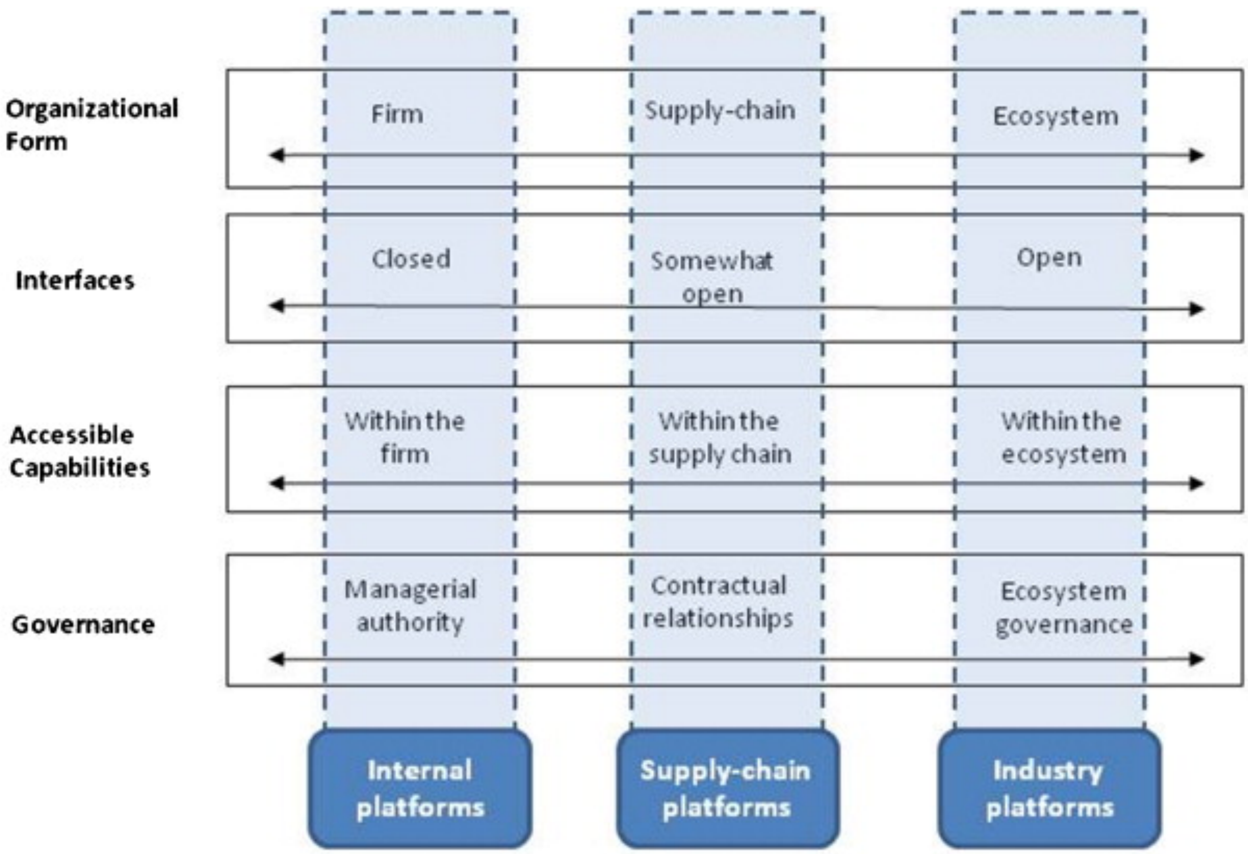

Figure 8 An Integrative Framework of Technological Platforms. [94]

2.2.3 Industrial platform ecosystem design- considerations and trade-offs

Multilateral interdependence is a key feature of platform ecosystem structure that enables delivery of value proposition using complementary capabilities beyond the capacity of any single firm. This gives rise to some important levers that can be used to design the platform ecosystem as discussed in this section.

Modularity

Modularity is an essential condition for the ecosystem to emerge as it enables clarity and stability in the core platform capabilities, allowing partners to share and build on top of the core platform. This reduces the cost of common platform infrastructure. Modular architecture results in trade-offs [95]. It allows separation and specialization of functions resulting in the development of partners that complement and enhance core value proposition. Modularity reduces the performance as compared to an integrated architecture due to decomposition of the functions. Modularity also results in incremental innovation as opposed to integrated architectures. Increased modularity results in increased risk of imitation and loss of leadership position.

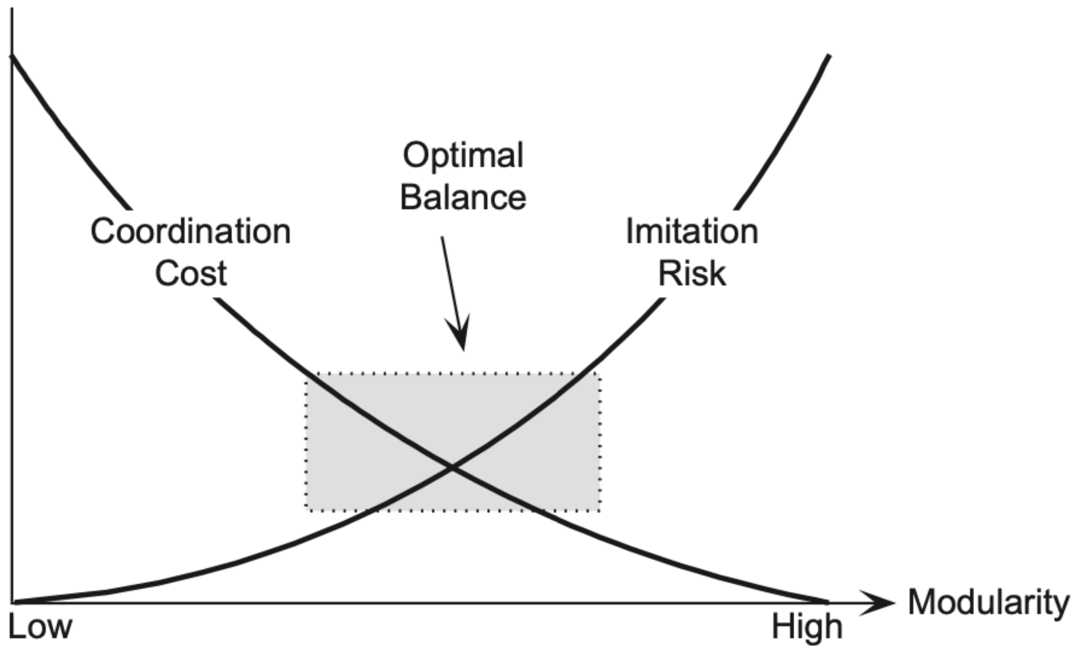

Figure 9 Coordination Costs vs. Imitation Risk with Modularity. [95]

Interface

Platform ecosystems require stable and well-defined interfaces to allow partners to access to the platform resources. Platforms leaders exert control over the ecosystem by controlling access to the interfaces. Interfaces can evolve with the ecosystem as the platform enters new markets.

Openness

Platform openness defines the degree to which the platform resources can be accessed by the complementors. Boudreau relates openness to the easing of restrictions on the use, development, and commercialization of a technology [49]. Schilling discusses the incentive to open the platform as driven by two main effects- learning curve advantages and network externalities [50]. Learning curve advantages come from the realization that as a technology becomes more adopted it is developed further and made more effective and efficient. Network externalities result from the finding that in some businesses the users see increasing benefits as the number of adopters increases as discussed by Katz and Shapiro [51] [52] [53].

Digital platforms supply programming interfaces or software development kits. Many of the Industrial Internet of Things platforms such as GE Digital and Siemens MindSphere have acquired low-code or no-code application development resources to make it easier to create applications.

Platform openness has a significant impact on platform development, the ability to control quality, and capture value by the platform leader. [49] Boudreau reports that- *granting greater levels of access to independent hardware developer firms produces up to a fivefold acceleration in the rate of new handheld device development, depending on the precise degree of access and how this policy was implemented. Where operating system platform owners went further to give up control (beyond just granting access to their platforms) the incremental effect on new device development was still positive but an order of magnitude smaller.* Gawer and Cusumano discuss the trade-off of opening the interfaces with the ability to capture value [54]. Thus, there is an optimum level of openness at which the platform can capture maximum value and spur the growth of complements.

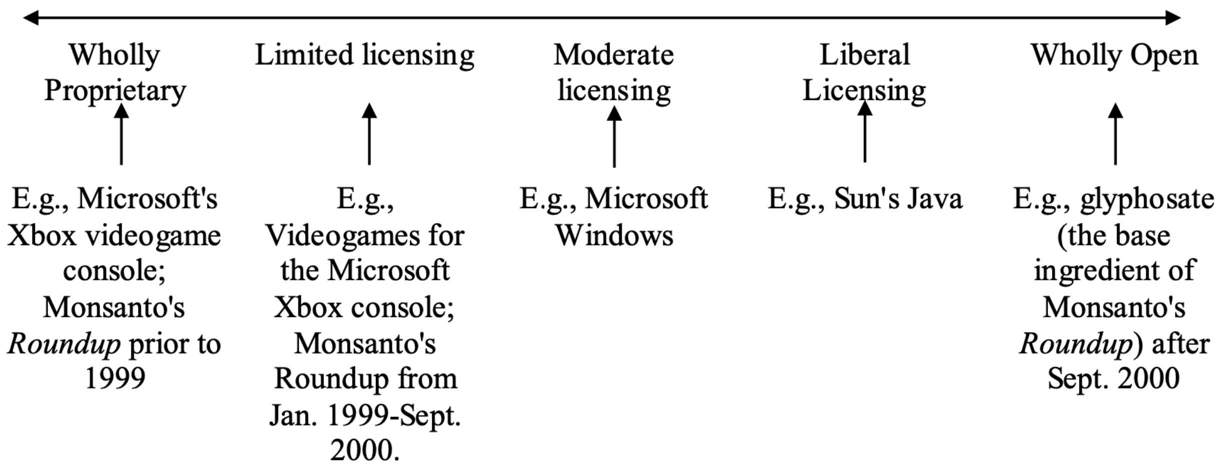

Figure 10 Openness Continuum Model. [50]

Schilling describes a continuum model based on the degree of openness as seen in Figure 10 [50]. There exists a goldilocks zone at which the platform can promote competition without giving away significant control over the revenue. Eisenmann, Parker, and Van Alstyne describe the four levels of openness depending on the participation of external partners for each role of a platform with examples of successful platforms [55]. Figure 12 shows different platform control categories- proprietary, joint venture, licensing, and sharing- as defined by the number of partners sharing the sponsor and operator roles.

	Linux	**Windows**	**Macintosh**	**iPhone**
Demand-Side User (End User)	Open	Open	Open	Open
Supply-Side User (Application Developer)	Open	Open	Open	**Closed**
Platform Provider (Hardware/OS Bundle)	Open	Open	**Closed**	**Closed**
Platform Sponsor (Design & IP Rights Owner)	Open	**Closed**	**Closed**	**Closed**

Figure 11 Platform Roles and Openness. [55]

		Who Provides the Platform (*Provider Role*)?	
		One Firm	**Many Firms**
Who Controls Platform Technology (*Sponsor Role*)?	**One Firm**	***Proprietary*** • Macintosh • Playstation • Monster.com • Federal Express	***Licensing*** • Palm OS • American Express-branded MBNA cards • Scientific-Atlanta set-tops
	Many Firms	***Joint Venture*** • CareerBuilder (created by three newspaper groups) • Orbitz (created by several major airlines)	***Shared*** • Linux • Visa • DVD • UPC barcode

Figure 12 Platform Control Categories Based on Sharing Structure. [56]

The decision whether to share the technology with other partners depends on the level of competition. Platform owners decide on sharing and collaborating to establish standards to reduce the chances of losing out on the market due to a single winner outcome in markets with strong network effects [56]. Sharing technology increases willingness to pay and promotes increased adoption due to reduction in the probability of the technology ending up as loser in a competitive market. It expands the market size and improves the effectiveness and efficiency of the technology due to learning effects. Network effects further promote adoption of the open standard. The value appropriated by the platform owner is a product of market size, market share, and margin.

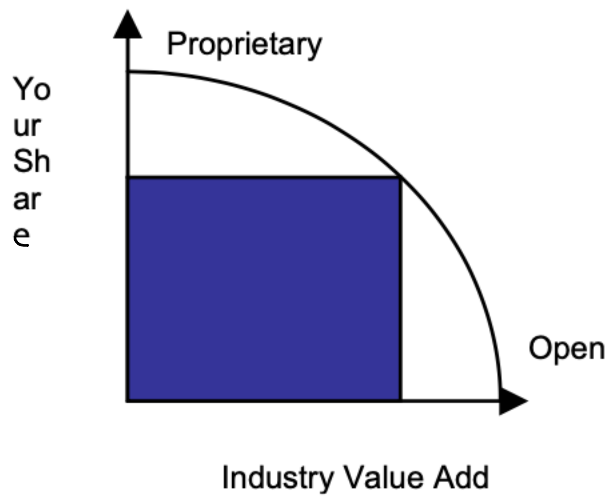

Figure 13 Platform Openness Trade-off. [56]

Complementors

Brandenburger and Nalebuff define a complement as- *a complement to one product or service is any other product or service that makes the first one more attractive* [59]. The lever of complementarity and number of complementors or sides of a platform are two of the important characteristics about platform complementors. Multi-sided platforms allow interaction of more than two sides. Multi-sided platform give rise to interesting price dependencies, wherein the platform leader could increase the value captured by subsidizing one side and allowing capture of increased value on the other side [20]. Greater the number of complementors, greater is the probability of platform success.

Jacobides, Cennamo, and Gawer consider complementarity as a key underpinning of the ecosystem structure that enables modularity and the basic hub and spoke architecture of the ecosystem structure [9]. They consider two types of non-generic complementarities- unique and supermodular- on the production and consumption side that are required for a system to be considered as an ecosystem. Unique complementarity between two products can be explained as when the value of one product is maximized with when used with the second product, supermodular complementarity can be explained as when more of one product makes the second product more valuable.

The complementarities and associated fungibility have an impact on the collaboration within the ecosystem [9]. Unique and supermodular complementarity with lower fungibility aligns the interests of partners together, increasing the chances of successful collaboration, though it also makes recruitment of new partners more difficult due to greater need of commitment.

2.3 Platform Competition

A successful platform needs to create and capture value in a sustainable manner. Platforms see competition between platform leaders, between platform leaders and complementors, and among complementors. A successful platform should manage these different tensions well to be profitable in a sustainable manner. According to a study of 100 platform ecosystems done by BCG 85% of platforms failed before reaching a sustainable stable stage [60]. A significant portion of these fail during the launch and scale stages due to inability to achieve critical mass.

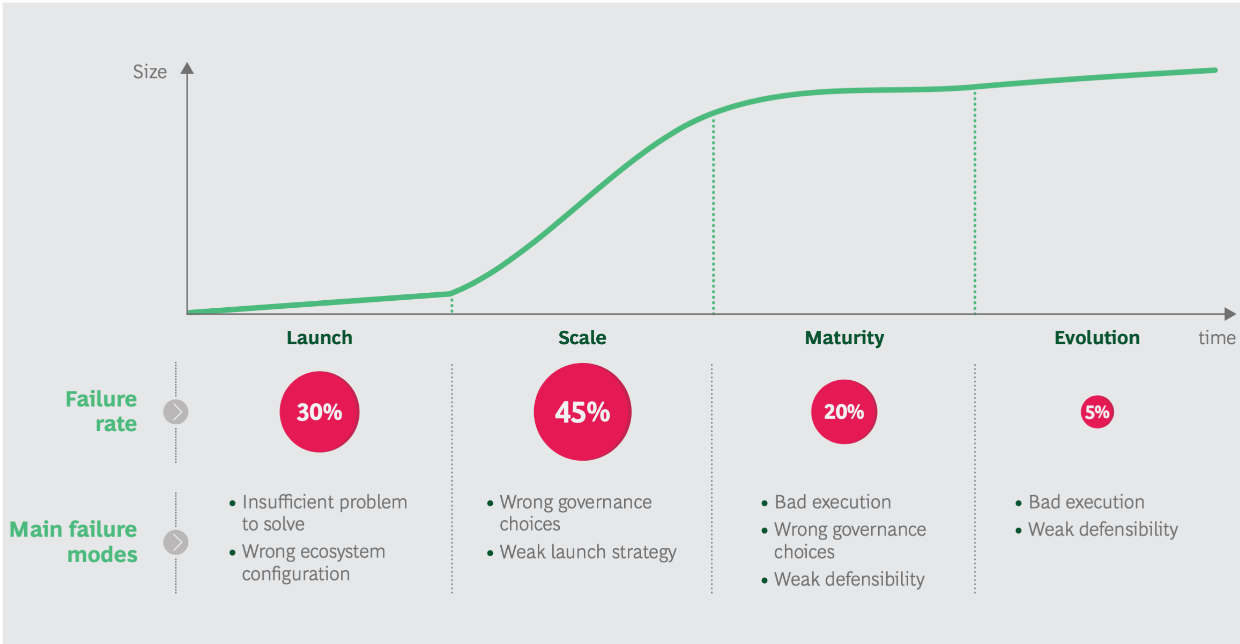

Figure 14 Failure Rate of Platforms with Time. [60]

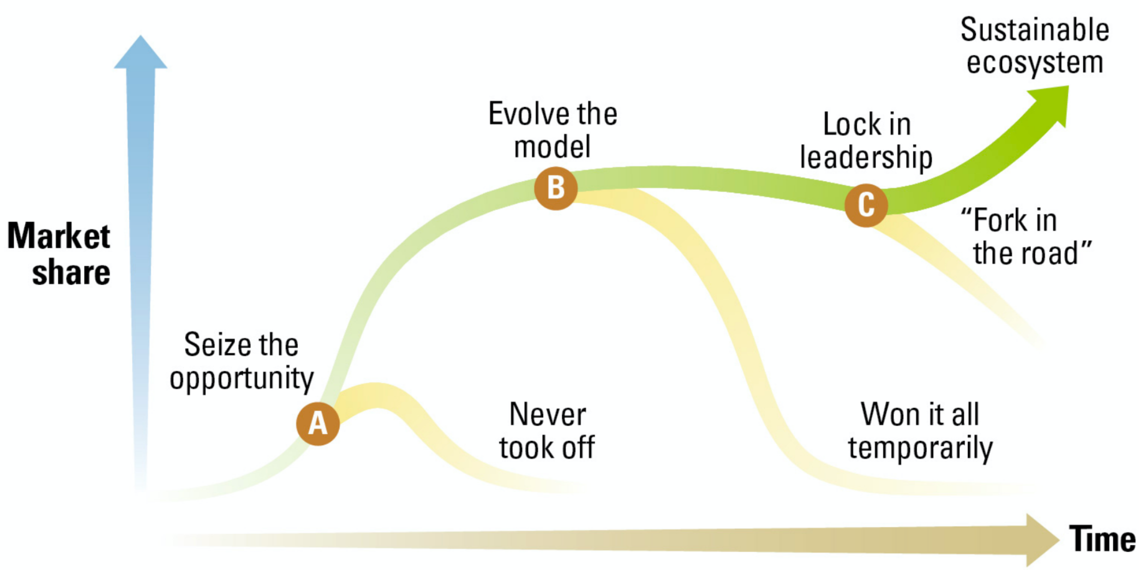

Figure 15 Platform Launch Outcomes and Opportunity Windows. [61]

Value creation and value capture are two important determinants of the platform profitability. The value captured by the platform depends on the customer willingness-to-pay and the cost. Platform customer WTP varies with the platform value, which is composed of stand-alone value and value due to network effects. Platforms can capture a significant portion of the surplus in winner-take-all markets. Competition in the platform industries show some unique characteristics, such as, path dependence, positive feedback, and winner-take-all effects.

According to Eisenmann, Parker, and Van Alstyne markets tend to result in Winner-take-all or winner-take-most outcomes if following three conditions are present [62]:

- Multihoming costs are high for at least one of the user sides.
- Network effects are positive and strong for the sides with high multihoming costs.
- Neither sides' users have strong preference for special features.

Evans and Schmalensee discuss how digital technologies have changed the winner-takes-all or most dynamics of platform markets due to low entry costs, trivial sunk costs, easy switching by customers, and rapid pace of disruptive innovations [63].

2.4 Platform Drivers

It is important to understand the primary drivers of platform competition that enable ecosystem success.

Network effects

Network effects arise due to demand interdependence and are demand side network externalities such that the value to existing customers increases with the acquisition of each subsequent customer. Porter discusses how network effects can make an industry structurally attractive with high barriers to entry, reducing threat of entrants and increasing profitability [65].

Network effects can be both positive and negative. Network effects can be classified as same side or direct network effect and cross-side or indirect network effects.

- Direct Network effects:
  Direct network effects are created by the effect of user on one side of the market on the users on the same side of the market.
- Indirect network effects:
  Indirect network effects are created by effects of users on one side of the market on the user on the other side of the market.

Tucker discusses characteristics of network effects [66]. Network effects are unstable in digital markets and don't necessarily lead to entrenched effects. Also, network effects have found to be local by Huotari and do not necessarily depend on the size of the entire network, but on the strength in the vicinity of the user [69]. Thus, network effects do not necessarily lead to market power unless followed by other measures.

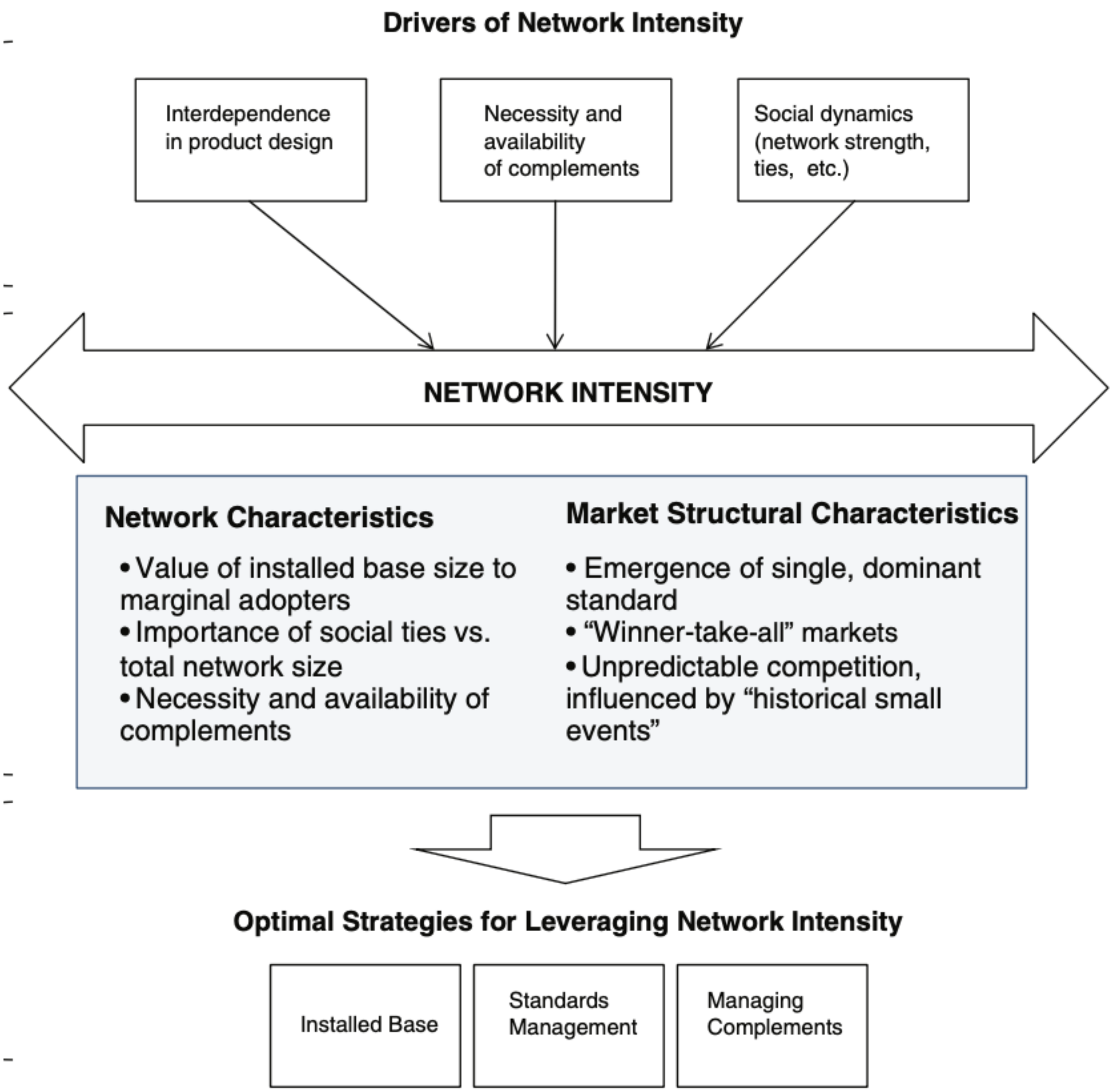

Figure 16 Drivers of Network Intensity. [67]

Network effects could be deliberately designed in the platform architecture resulting in interdependence within or between sides [67]. McIntyre and Subramaniam suggest interdependence in product design, necessity and availability of complements, and social dynamics as three primary factors that drive network effects. Network effects could be assessed based on the value of the network to a marginal adopter and market structural attributes [67]. Markets with strong network effects show increase and stability in relative market shares, whereas low network effects indicate multiple standards with a fragmented market, customers value both network and stand-alone value. Lee, Lee, and Lee modeled the effects of allowing greater freedom to connect with other participants as opposed to controlling the connections and show that it results in a fragmented market, whereas increased connections result in winner-take-all or winner-take-most outcomes with one market leader [68]. Another result shows that in the simulation an initial market share of 70% is required for monopoly outcomes.

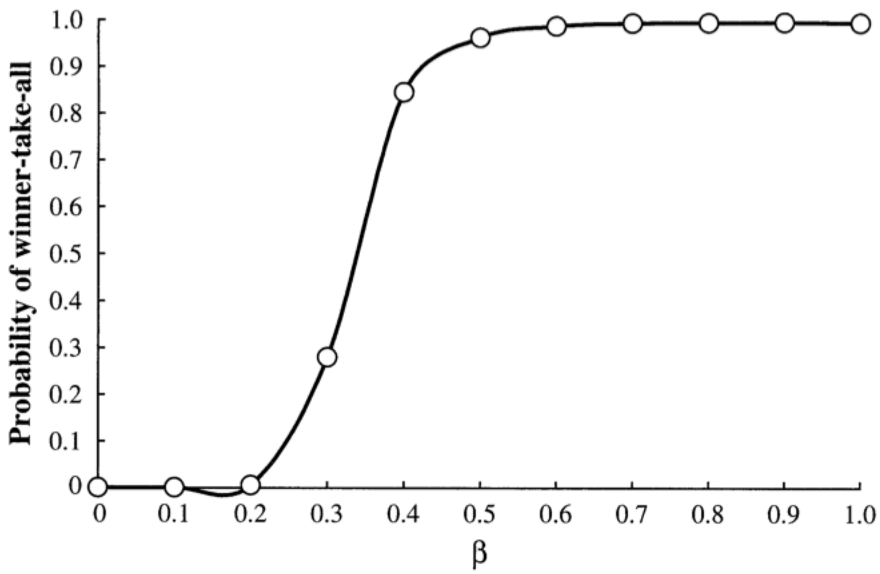

Figure 17 Probability of winner-take-all outcome with increased connections between partners. [68]

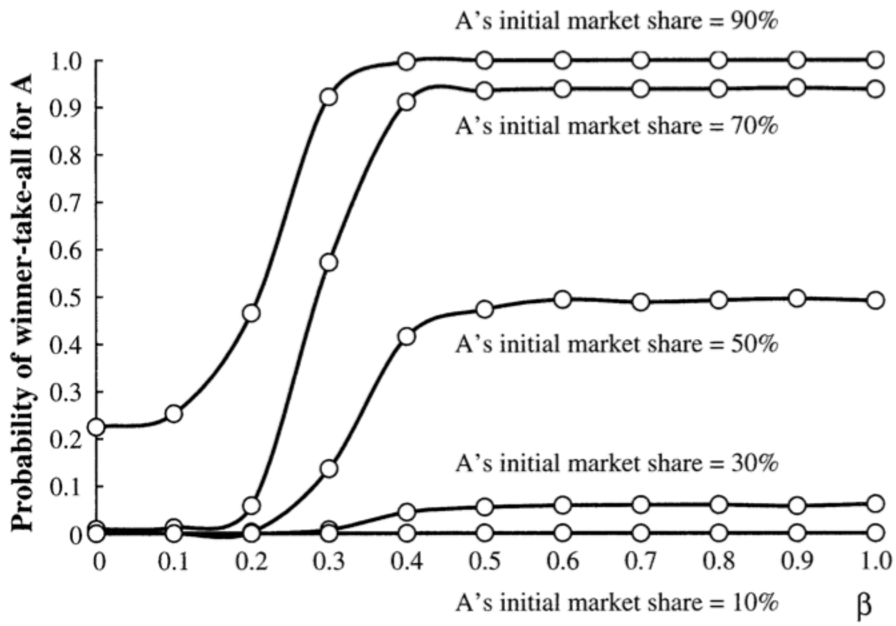

Figure 18 Probability of winner-take-all outcomes with initial market share. [68]

Currier lists 13 types of network effects and arranges them according to their strength [70]. It is interesting to note that data network effects are considered as weak network effects. The network effects are:

1. Physical
2. Protocol
3. Personal utility
4. Personal
5. Market networks
6. Marketplace
7. Platform
8. Asymptotic marketplace
9. Data
10. Tech performance
11. Language

12. Belief
13. Bandwagon

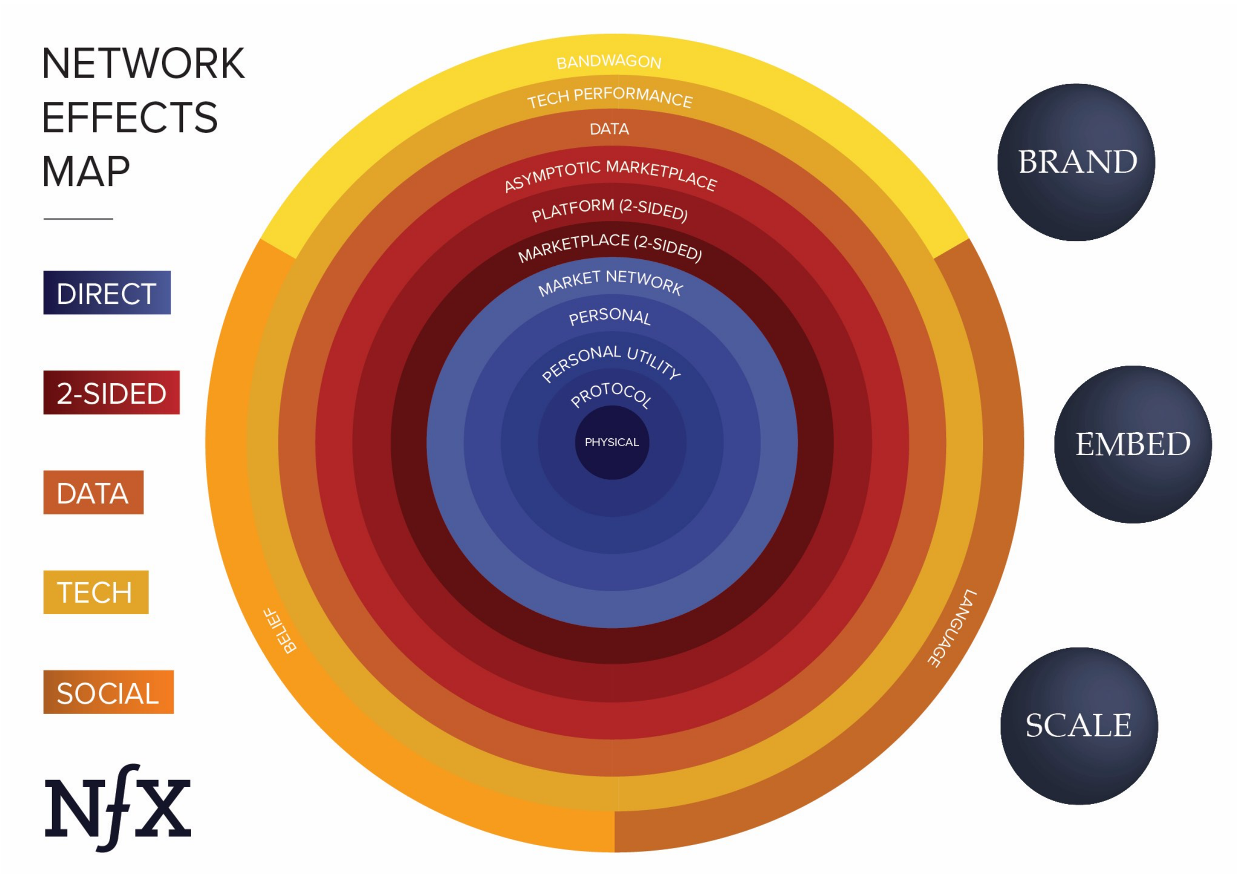

Figure 19 Types of Network Effects. [70]

Differentiation

A fragmented market with niche players and differentiated offerings prevents emergence of a winner-take-all or winner-takes-most outcomes by making differentiated offerings more valuable than the network value derived from being associated with large size network, as shown by Lee, Lee, and Lee [68].

Multihoming

Cusumano explains how multihoming even prevents markets with strong same-side network effects from monetizing cross-side network effects [16]. New market entrants prefer multihoming so that they could attract users from the incumbent, whereas the incumbent restrict multihoming. Differentiated offerings allow more value to be captured and can be very profitable for the platforms, even if the market share is low, as in the case of Apple iPhone, which derived 80% of smartphone profits with 18% market share.

Entry Barriers

In platform markets, where switching costs are high or that need high ecosystem infrastructure investments, new entrants face significant entry barriers.

2.5 Platform Strategy

The aim of a platform strategy is to attain critical mass and establish the platform for sustainable growth. There is considerable literature that identifies successful strategies, which could be classified between those for new platforms and established platforms.

McIntyre and Subramaniam classify platform strategy initiatives between two areas [67]:

- Developing an installed base

Developing an installed base and reaching critical mass is an important equilibrium point for network platforms as defined by the industrial organization theory.

- Managing the influence of complementary products.
  Availability of complementary products has been identified as an important growth factor for platforms.

Zhu and Iansiti study the video game industry to study the relative importance of indirect network effects, future expectations, and platform quality and show that, when network effects are low, market is quality driven and oligopoly exists in the market, whereas as network effects become strong market tips to monopoly and entrants are at a disadvantage [79]. Thus, developing stronger network effects ad installed base make entry of new entrants difficult.

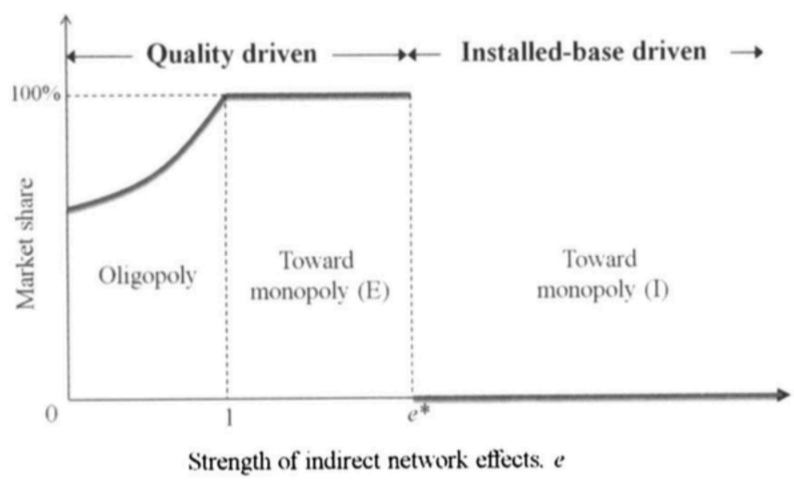

Figure 20 Market Share Variation of New Entrant with Strength of Indirect Network Effects. [79]

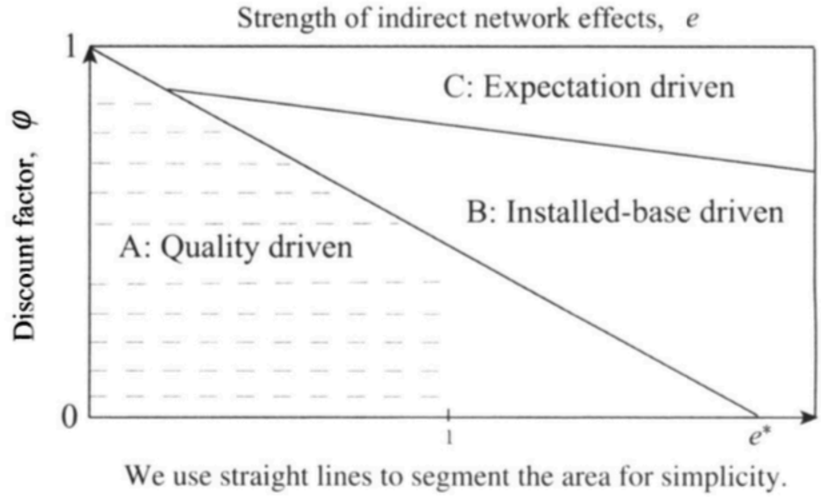

Figure 21 Strength of Indirect Network Effects vs. Discount Factor as a Driving Factor. [79]

Gawer and Cusumano classify strategies for wannabe platform leaders as shown in the figure - coring and tipping [71].

Coring is defined as solving an essential system problem while allowing external complementors to build on the capabilities [71] [16]. This inverts the firm and reduces the requirement of internal resources. At the same time, it allows faster time-to-market due to availability of substitutable complementors with relevant skills. Coring with proper interface design for external partners to join is the fundamental task in creation of a platform.

Tipping creates a momentum for more and more partners to join the platform ecosystem [71] [16]. Network platforms exhibit path dependency (i.e. past results determine future outcomes), making it an essential part of the strategy to establish a successful platform.

Strategic Option	Technology Actions to Consider	Business Actions to Consider
Coring How to create a new platform where none existed before	• Solve an essential "system" problem • Facilitate external companies' provision of add-ons • Keep intellectual property closed on the innards of your technology • Maintain strong interdependencies between platform and complements	• Solve an essential business problem for many industry players • Create and preserve complementors' incentives to contribute and innovate • Protect your main source of revenue and profit • Maintain high switching costs to competing platforms
Tipping How to win platform wars by building market momentum	• Try to develop unique, compelling features that are hard to imitate and that attract users • Tip across markets: absorb and bundle technical features from an adjacent market	• Provide more incentives for complementors than your competitors do • Rally competitors to form a coalition • Consider pricing or subsidy mechanisms that attract users to the platform

Figure 22 Coring and Tipping Strategies. [71]

For existing platform leaders, Cusumano and Gawer list four levers [72]:

- Scope- *it is the amount of innovation the company does internally and how much it encourages outsiders to do*.
- Product technology- it relates to the decisions about modularity, how open the interfaces are to be, and the amount of information disclosed to the outsiders.
- Relationships with external complementors- platform leaders need to decide how competitive or collaborative do their relationships with complementors should be.
- Internal organization- internal organizations need to be designed to manage conflict or interests.

In network businesses as platforms, it is important to reach critical size to ensure lift-off. The strategies used towards this purpose are:

- Bundling

- Discounting in one market to capture value in another market with greater increase in willingness-to-pay
- Enveloping
- Launching in a smaller target market before expanding
- Registering users with free cancelation
- Providing the service free for a limited period of time

2.5.1 Platform Launch

Cusumano, Gawer, and Yoffie list four steps in launching a platform [16]:

1. Choose market sides
   Choosing the correct market sides is very important. Cusumano lists starting with too many sides, failing to identify the side that attracts others, mispricing the attractive side, and entering a market too late as some of the mistakes.
2. Solve the chicken-or-egg problem
   Cusumano explains that strategic choices fall in one of the three categories: creating stand-alone value for one side first, subsidizing one or both sides, and bringing two sides on-board simultaneously.
3. Design business model
   A business needs to develop a business model that is sustainable. Cusumano explains that innovation platforms generate profit by either increasing customer's willingness to pay or charging per transaction, while transaction platforms generate revenue by one of five ways- matchmaking, reducing friction in transactions, complementary services, complementary technology sales, and advertising.
4. Establish and enforce rules

Establishing and enforcing rules is an important part of governance. It should be done in a way so that the platform generates trust by fair policies. Deciding who should and should not participate is an important part of the governance and helps maintain quality and customer interest. Atari faced a problem of too many bad quality games that tarnished its image. Platforms face a balancing act while making sure that they come across as fair to their complementors who fear them as potential competitors due to information asymmetry. Intel handles this beautifully by creating Intel Architecture Lab, a not-for-profit unit separate from its primary business operations. This work discusses some of the similar trust issues faced by GE Digital and others in the IIoT platform markets.

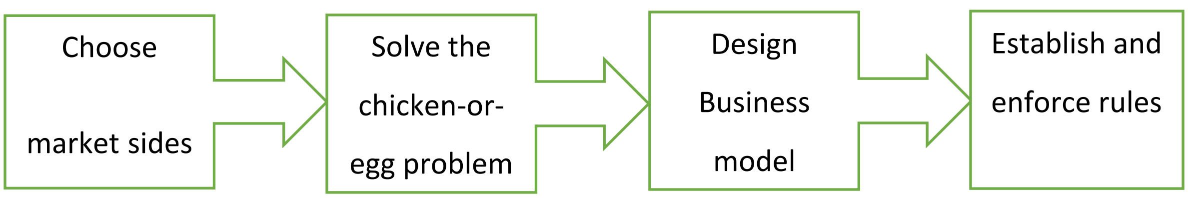

Figure 23 Platform Launch Stages. [16]

3. Digital Transformation, Industrial Internet of Things, and Use Cases

This chapter provides an overview of the technology involved in IIoT, the use cases, business models, and market forecast.

3.1 Digital Transformation and Industry 4.0

We are living in the era of fourth industrial revolution enabled by digital transformation. A BCG report describes Industry 4.0 as - ‘The rise of new digital industrial technology, known as Industry 4.0, is a transformation that makes it possible to gather and analyze data across machines, enabling faster, more flexible, and more efficient processes to produce higher-quality goods at reduced costs [8]. This manufacturing revolution will increase productivity, shift economics, foster industrial growth, and modify the profile of the workforce—ultimately changing the competitiveness of companies and regions.’

According to BCG, there are nine disruptive technologies that are enabling industry 4.0 transformation [8]:

- Industrial internet of things
- Additive manufacturing
- Autonomous robots
- Horizontal and vertical system integration
- Big data and analytics
- The cloud
- Cybersecurity
- Augmented Reality

- Simulation

Deloitte lists following steps for companies undergoing digital transformation [100]:

- Decide strategy
- Choose your business model
- Acquire capabilities
- Decide your operating model
- Organize and acquire people, process, and technology

3.2 IIoT

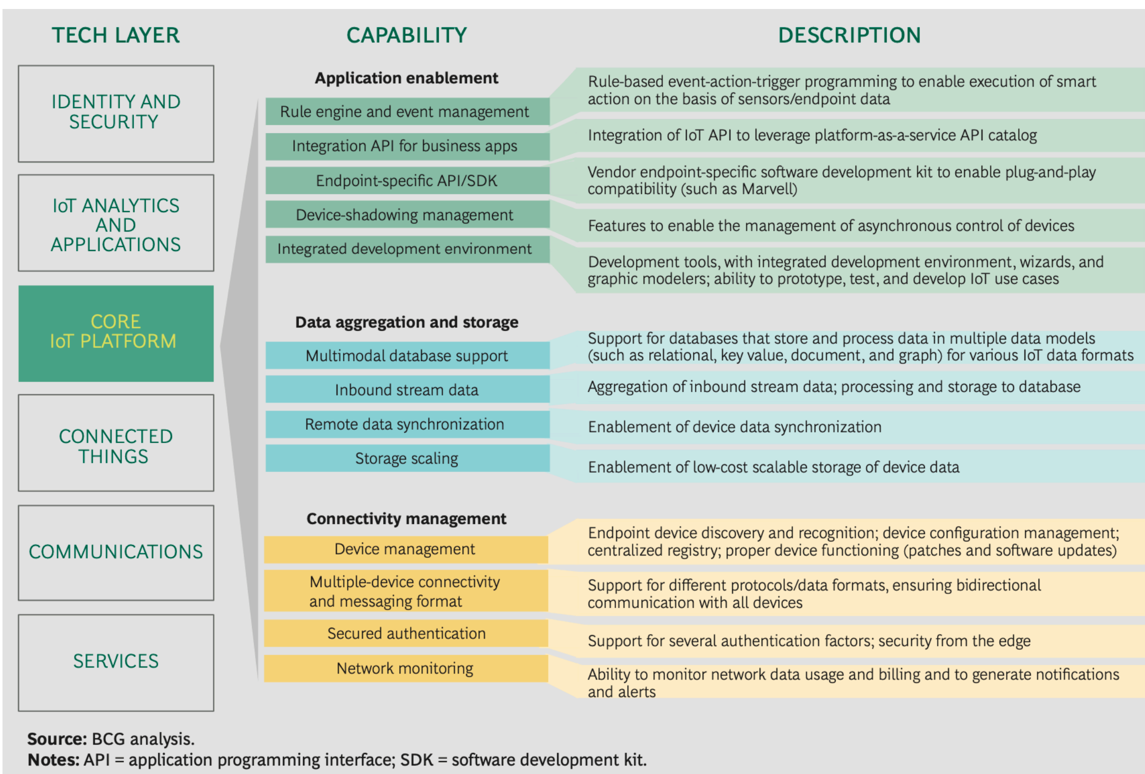

Figure 24 Complete Core IIoT Platform Capability. [101]

The IoT stack consists of three tiers at a high level [107]:

- Edge- This consists of the devices from where data is connected, the sensors, gateway, and connectivity, which provides communication between the devices and gateways and platform components.
- Platform- It consists of the backend components that enable the IoT capability. It includes connectivity management, data aggregation and storage, application enablement, analytics, monetization and billing, security and access management, service APIs, enterprise integration.
- Enterprise- This includes business applications, marketplace, analytics and data visualization, services, enterprise integration, and rules.

3.3 Use Cases

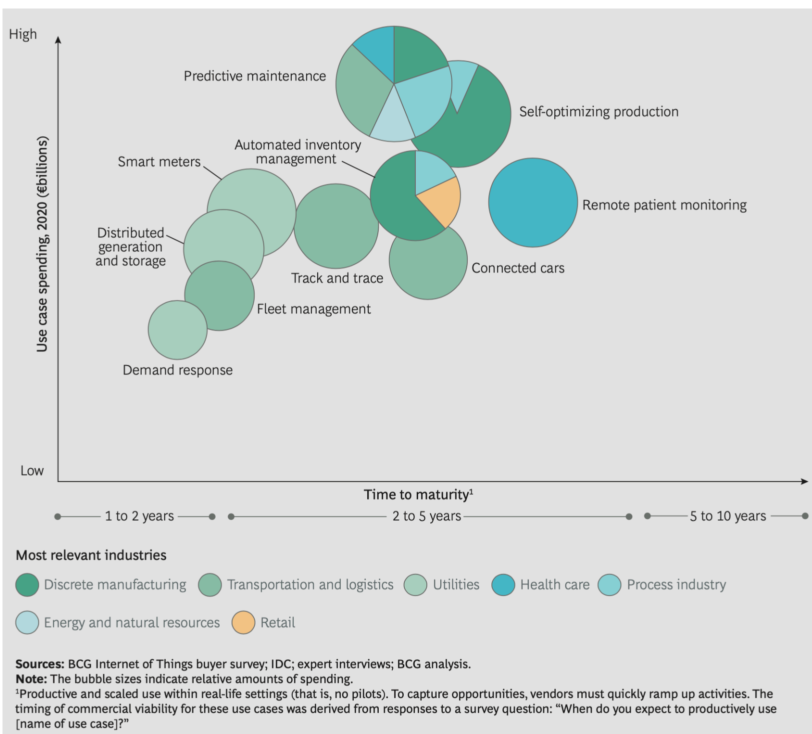

Figure 25 IIoT Use Cases. [102]

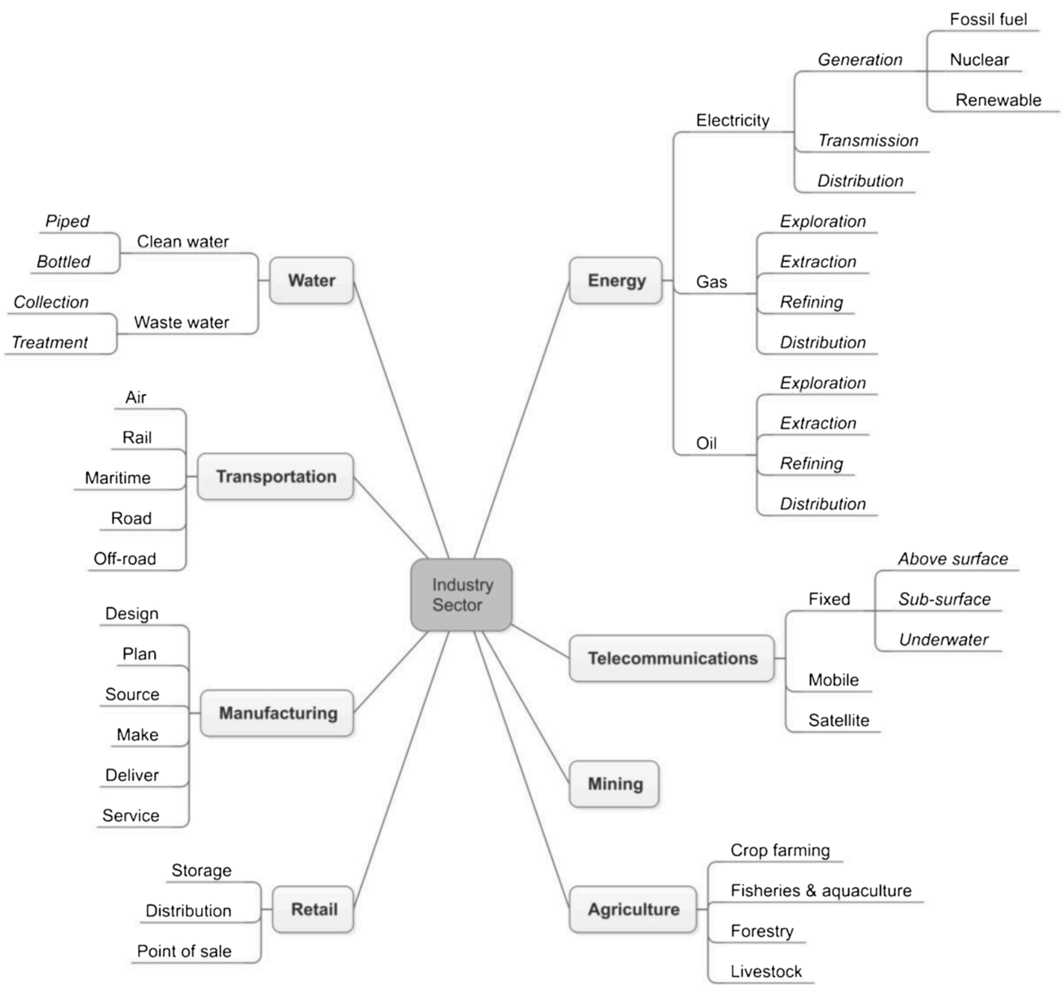

Figure 26 IIoT Industry Sectors. [103]

3.4 Business Models

There are multiple pricing models that are used by IIoT software providers:

- Subscription based pricing
- Pay-as-you-go pricing
- Tiers of application functionality
- Revenue sharing model

Figure 27 lists the business models of various industrial companies, which shows considerable variety.

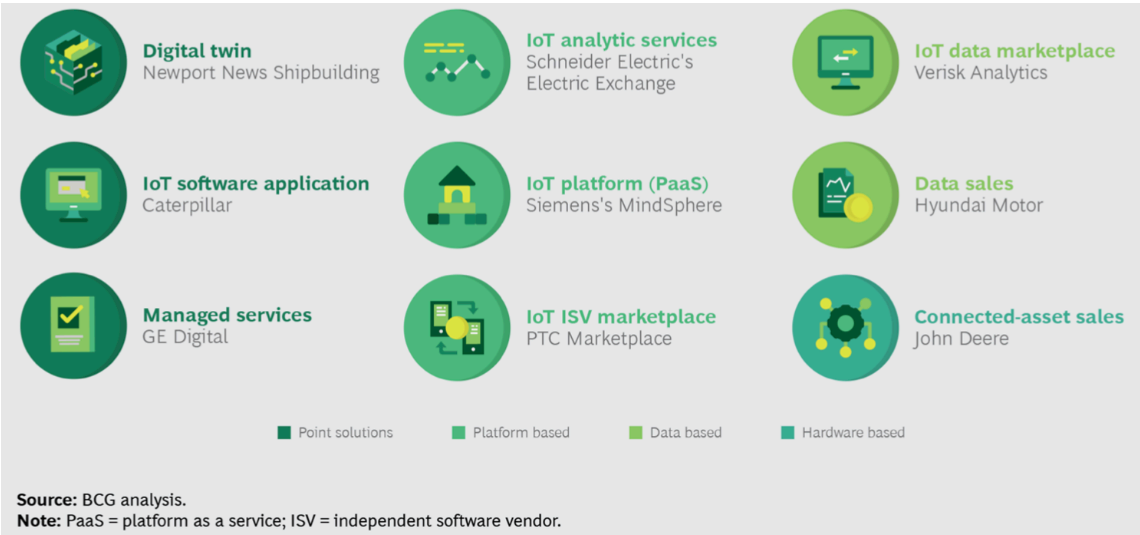

Figure 27 Business Models of Various IIoT Businesses. [104]

As-a-service business model is one of the most commonly used business models enabled by digital industrial capabilities and is often described as pay-as-you-go model [106]. It trades some of the capital expenditure to operational expenditure in the financial statements and reduces the upfront cost, making it suitable for startups and small businesses. The customer buys a minimum value rather than a product and the business is responsible to deliver the value. Any surplus value above the targets is usually shared with the business. The incentives for the business and customer are well aligned for long term growth.

3.5 Market Size and Future Trends

IIoT has been one of the fastest growing industrial segments with 20-30% compound annual growth rate. Manufacturing, transportation, and utilities have seen most of the spending so far. As per BCG, all layers of technology stack will see considerable growth, but services, IoT applications, and analytics capture 60% of IoT spending. This presents a significant opportunity for startups and incumbent companies with digital capabilities.

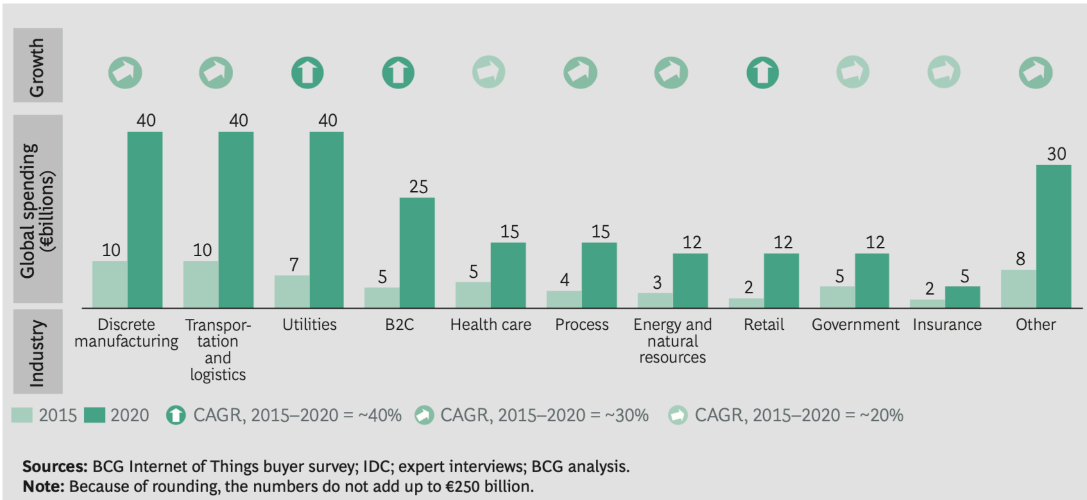

Figure 28 Market Size by Spending on IIoT. [102]

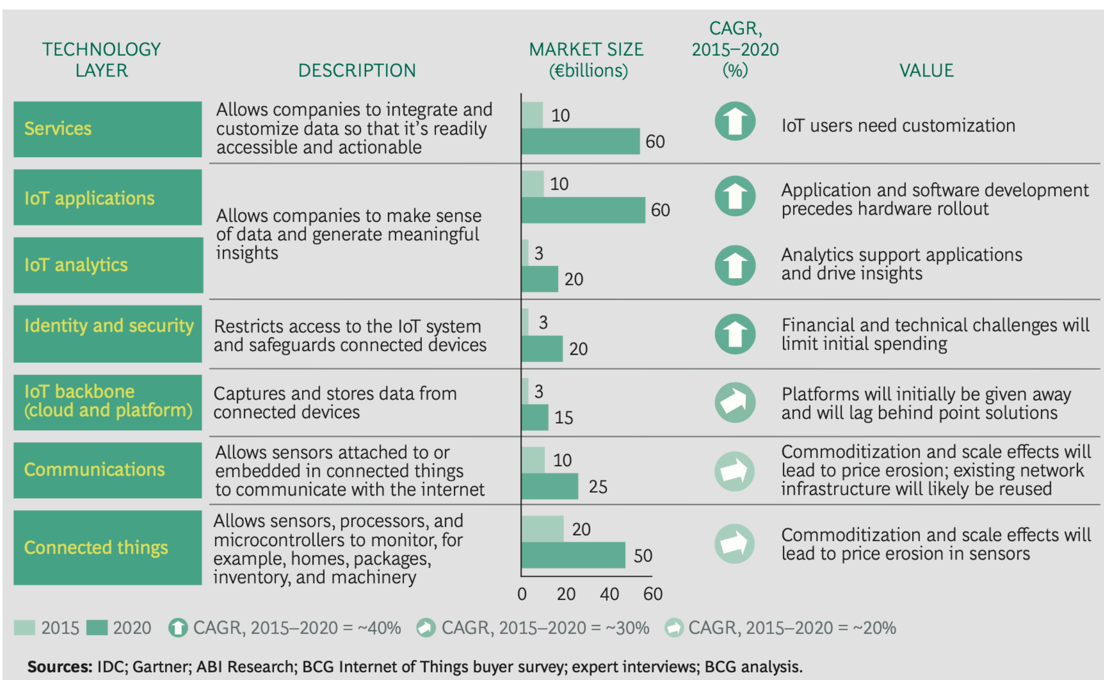

Figure 29 Market spending in IIoT technology stack. [102]

5G, AI, and Augmented Reality are the most important technologies that will increase the capability and spread of IIoT. Future and current trends that present opportunities for new businesses include- move to edge computing as costs of edge devices is decreasing, increased focus on security, availability of more connectivity options with the rollout of NB-IoT/ LTE-M by telecommunication companies. Businesses will have to change to effectively adopt to incorporate IIoT capability. For example, with the adoption of XaaS model businesses will have to reorganize their internal structure and partner ecosystems to deliver their offerings as a service.

4. IIoT Platforms - Case study

[4]A Business Insider article reported about the then GE CEO Jeff Immelt's speech at the fifth annual Minds+Machines conference in 2015:

> *GE's software business is "growing 20 percent per year, and we have about $6 billion in orders this year. We'd like to be at $10 billion by 2020," he explained to Business Insider. (GE later clarified that they want to be at $15 billion by that date.) "On our current trajectory, GE is on track to be a top 10 software company".*

A lot of water has flown down the Charles river in Boston, where GE's world headquarter is located. These projections are a far cry from the current financial performance of GE's software business GE Digital, a company that coined the term 'Industrial Internet'[5]. What strategy did GE Digital use? Where did it go wrong?

This chapter analyzes GE's strategy from a platform perspective and compares it with the strategy adopted by Siemens' MindSphere platform.

4.1 Market Analysis and Perceptual mapping

IIoT market is fragmented with many digital platforms crowding the space. The market exhibits fierce competition among companies with no dominant player. The list of companies with IIoT offerings include old industrial companies such as GE, Siemens,

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[4] https://www.businessinsider.com/ge-ceo-jeff-immelt-top-10-software-company-2015-9

[5] https://www.ge.com/digital/blog/what-industrial-internet-things-iiot

ABB, Bosch, Honeywell, etc. and non-industrial companies such as Microsoft, C3.ai, PTC among others.

The market exhibits differentiated needs with a variety of applications that use different data schemas, protocols, data speeds, etc., [83]. Also, the market has high multi-homing costs as significant customization is required for each application and implementation. The market has weak data network effects based on the improvements in analytics capabilities with increase in data and user base for similar applications.

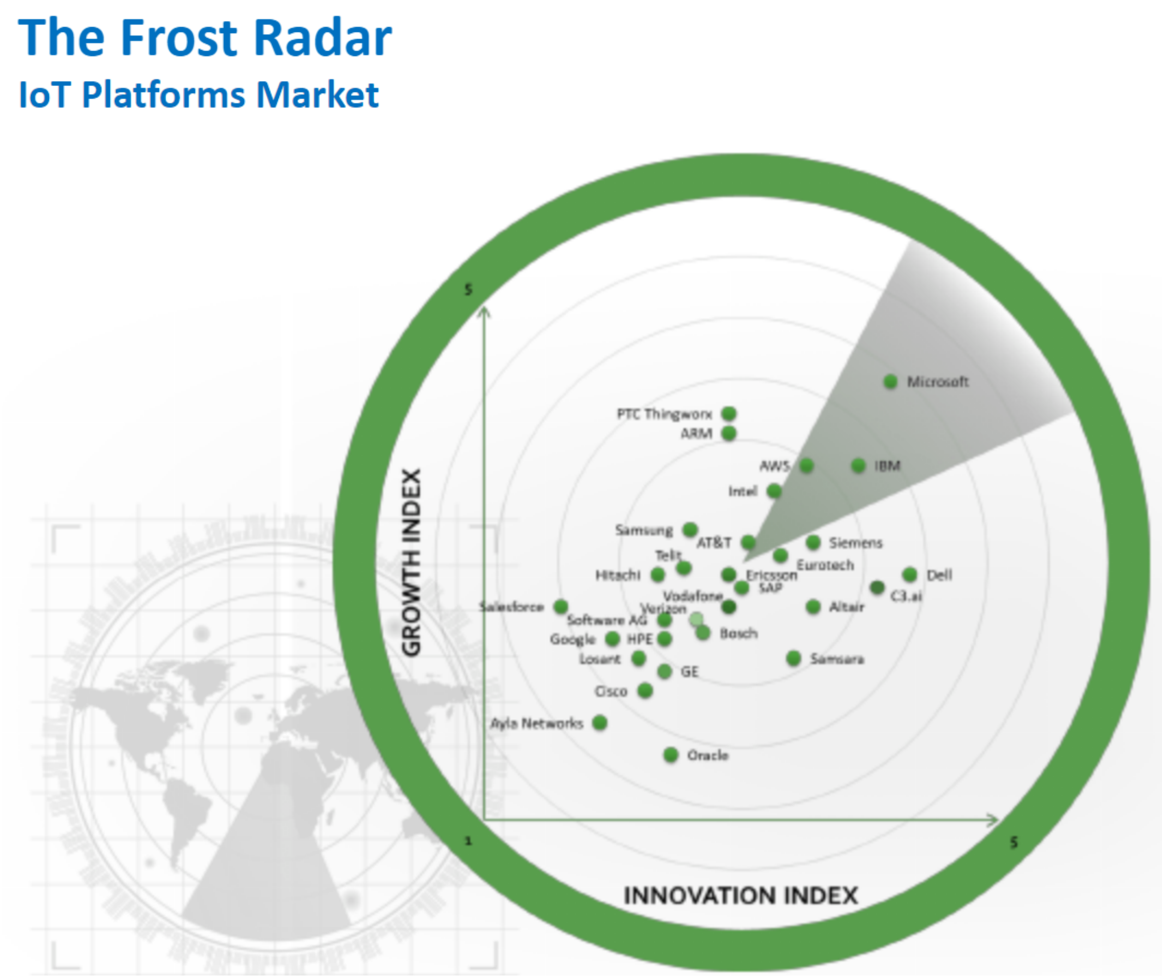

Figure 30 Frost & Sullivan IoT Market Report. [13]

The Frost and Sullivan IoT market report compares companies based on their growth and innovation and growth. It can be seen that Microsoft, AWS, and IBM, all technology companies, are the leaders followed by Siemens and others. GE lags behind many of its competitors on these metrics. The Forrester Wave market report has Siemens as the only industrial company among the leaders with C3.ai, PTC, and Microsoft.

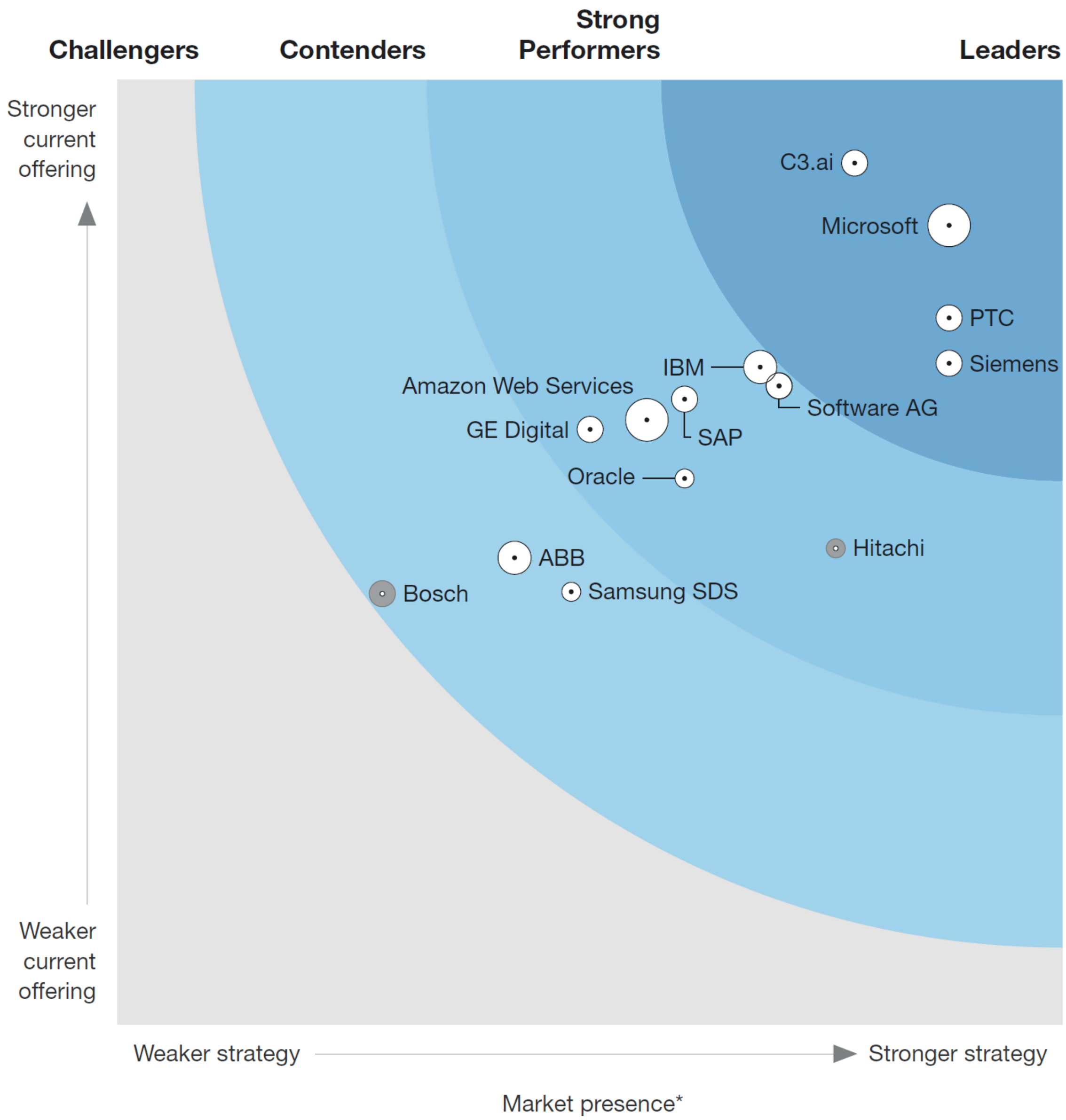

Figure 31 Forrester Wave market competitive analysis. [14]

4.2 Case Study-GE Digital

4.2.1 Background

General Electric Company is an iconic American multi-national conglomerate incorporated in 1892 by the merger of Thomas-Houston Electric Company and Edison General Electric Company that was founded in 1878 by Thomas Edison. It was a founding member of the Dow Jones Index. The Forbes company page for GE[6] says:

General Electric Co. is a technology and financial services company. It operates through the following segments: Power, Renewable Energy, Aviation, Healthcare, and Capital. The Power segment offers technologies, solutions, and services related to energy production, which includes gas and steam turbines, generators, and power generation services. The Renewable Energy segment provides wind turbine platforms, hardware & software, offshore wind turbines, solutions, products & services to hydropower industry, blades for onshore & offshore wind turbines, and high voltage equipment. The Aviation segment provides jet engines & turboprops for commercial airframes, maintenance, component repair, and overhaul services, as well as replacement parts, additive machines & materials, and engineering services. The Healthcare segment provides healthcare technologies in medical imaging, digital solutions, patient monitoring, and diagnostics, drug discovery, biopharmaceutical manufacturing technologies and performance enhancement solutions. The Capital segment leases & finances aircraft, aircraft engines and helicopters, and also provides financial and underwriting solutions. The company was founded by Thomas Alva Edison in 1878 and is headquartered in Boston, MA.

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[6] https://www.forbes.com/companies/general-electric/?sh=546e558a3970

GE Digital is a subsidiary of the General Electric company and provides software and IIoT services to industrial companies. It was a pioneer in bringing digital connectivity and analytics capabilities to the hardware industrial world and one of the original pioneers of in the IIoT market with its Predix digital platform.

GE's entry in the IIoT platform market was announced by the then CEO Jeff Immelt in 2015. GE launched the Predix platform in 2016 to the market and was on track to spend $5 billion on its digital efforts by the end of that year[7]. Due to financial troubles, Jeff Immelt was replaced in 2017 by John Flannery, who was replaced by Larry Culp in 2018. GE announced plans to spin-off the IIoT digital industrial division GE Digital as a separate company, but later changed plans to retain it within GE with P&L included in the Corporate business.

Currently, GE Digital has 21,000 customers worldwide and operates in the following markets: Aviation, Manufacturing and Digital Plant, Power Generation, Oil and Gas, Electric Grid and Utilities as core markets along with Food and Beverage/ CPG, Water and Wastewater, Pharmaceutical and Life Sciences, Telecommunications, and Automotive. In the annual report for 2020, GE reported that GE Digital has reached the revenue of $ 1 Billion[8], which is $ 14 Billion short of the initial projections.

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[7] https://www.wsj.com/articles/the-dimming-of-ges-bold-digital-dreams-11595044802?mod=djemalertNEWS

[8] 2020 GE Annual report https://www.ge.com/sites/default/files/GE_AR20_AnnualReport.pdf

4.2.2 Digital Platform

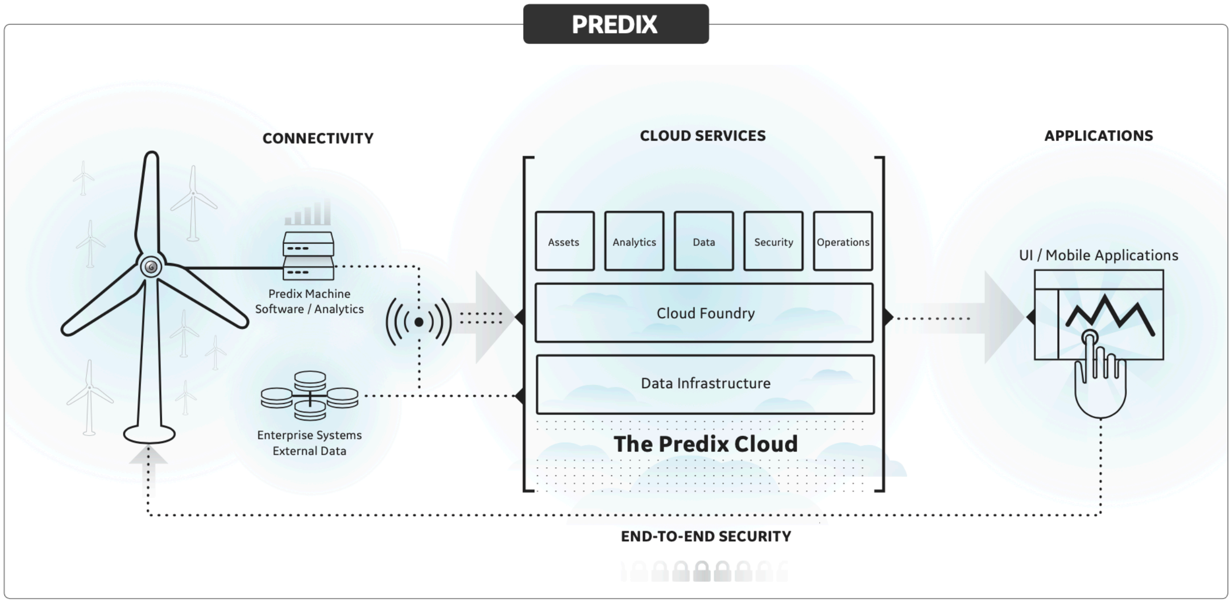

Figure 32 Predix Architecture. [9]

Written in 2015, GE's Digital Industrial Transformation Playbook[10] describes its ambitions to be a digital industrial company by defining it as:

At its core, a digital industrial company uses data and analytics to create a "digital twin" of each of its key processes and physical assets. This digital foundation enables the company to drive down costs while delivering consistent quality.

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[9] https://ecosystems4innovating.files.wordpress.com/2016/11/predix-the-platform-for-the-industrial-internet-whitepaper.pdf

[10] GE's Digital Industrial Transformation Playbook https://www.ge.com/digital/sites/default/files/download_assets/ge-digital-industrial-transformationplaybookwhitepaper.pdf?mkt_tok=eyJpIjoiTURKaU1tSXlPRGs1TjJJdyIsInQiOiJTdmdlVGlTenlCY3ZKMWRyeFRq

The end-to-end platform that positioned GE as an IaaS, PaaS, and SaaS player offered clear value proposition to the users and developers. It enabled users to connect GE and non-GE machines to capture, store, and analyze data and draw insights from it. It promised developers to provide ability to build, test, deploy, and scale applications quickly on a global scale using ecosystem partners.

Platform Architecture

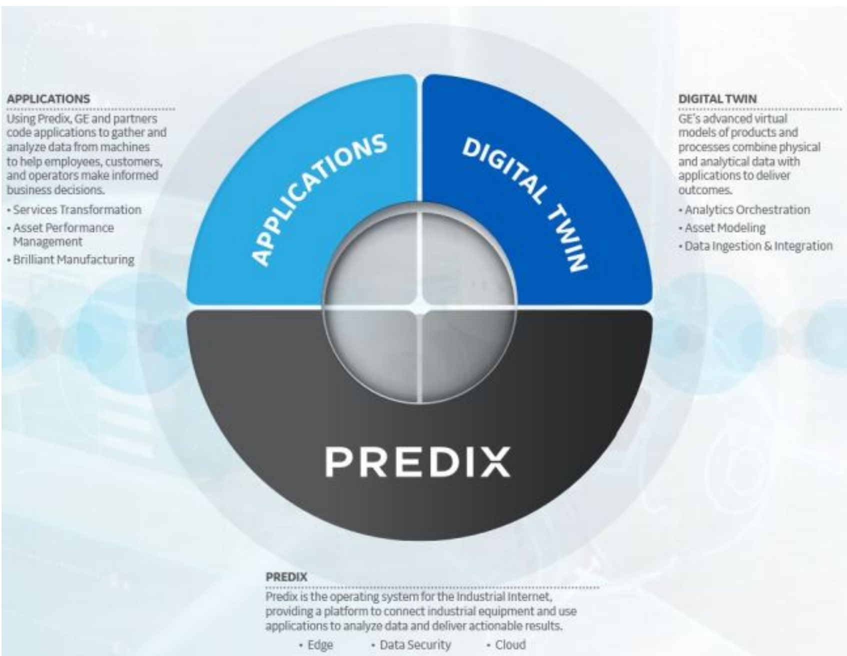

Figure 33 Predix Functionality Overview. [11]

GE built the platform using open architecture on Cloud Foundry, a not-for-profit PaaS organization. Predix was envisaged to be the operating system used by anyone wishing to connect and run physical assets in the digital world. Digital twin models of physical

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[11] General Electric. 2016. Leading A Digital Industrial Era. 2016 Annual report

assets and processes were designed to be at the heart of the edge-to-cloud platform combined with predictive analytics. It was designed to be modular with the support of microservices.

It supported many protocols, including OPC-UA, DDS, and MODBUS with TCP based socket communication. It included standard connectors for time series, location, ERP, and CRM, but also allowed building of customer connectors to work with proprietary data schemas. It was designed to work with Java, Node.js, Python, Artifactory, GitHub, JaCoCo, and Ruby on Rails for programming and Java, MATLAB, and Python for analytics. It supported HTML5 for use with desktop browsers, smartphones, and tablets.

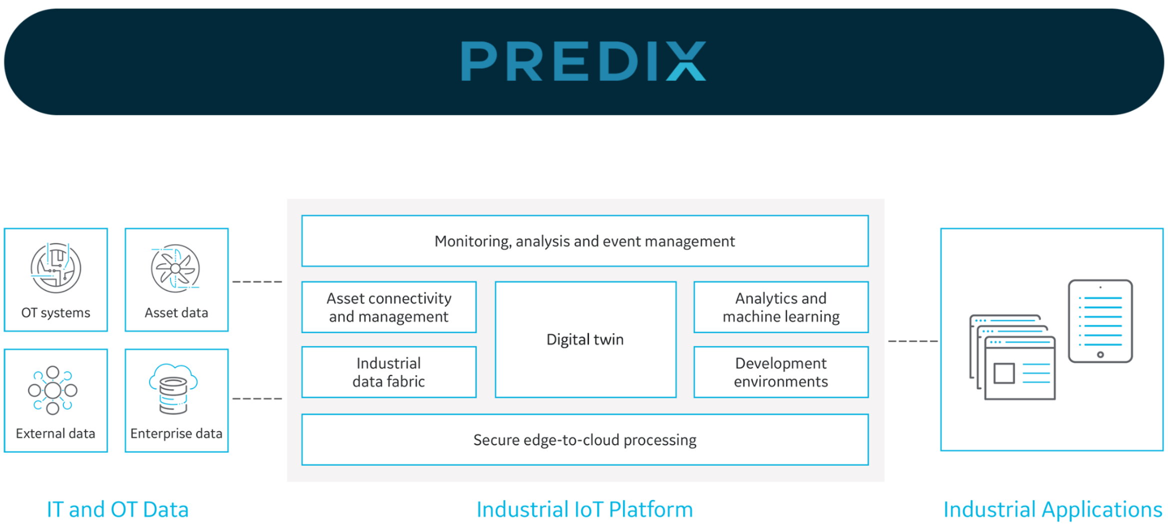

Figure 34 GE Predix platform architecture. [12]

Predix offered multiple services to the industrial customer/ user:

[12] https://ecosystems4innovating.files.wordpress.com/2016/11/predix-the-platform-for-the-industrial-internet-whitepaper.pdf

- Cloud infrastructure
- Connectivity as a service
- Asset services for modeling assets
- Data services for connecting to the source, data ingestion, pipeline processing, and data management
- Analytic services for descriptive, predictive, and prescriptive analytics

For developers Predix provided:

- Microservices to rapidly create and deliver applications
- DevOps tools for agile planning, source control management, automated build and deploy, and load testing of applications
- BizOps tools to assist with application use analytics and decision support

It also provided security as a part of the platform to secure and certify operational infrastructure, ensure operational availability and governance with IT, secure industrial apps, and monitor continuously.

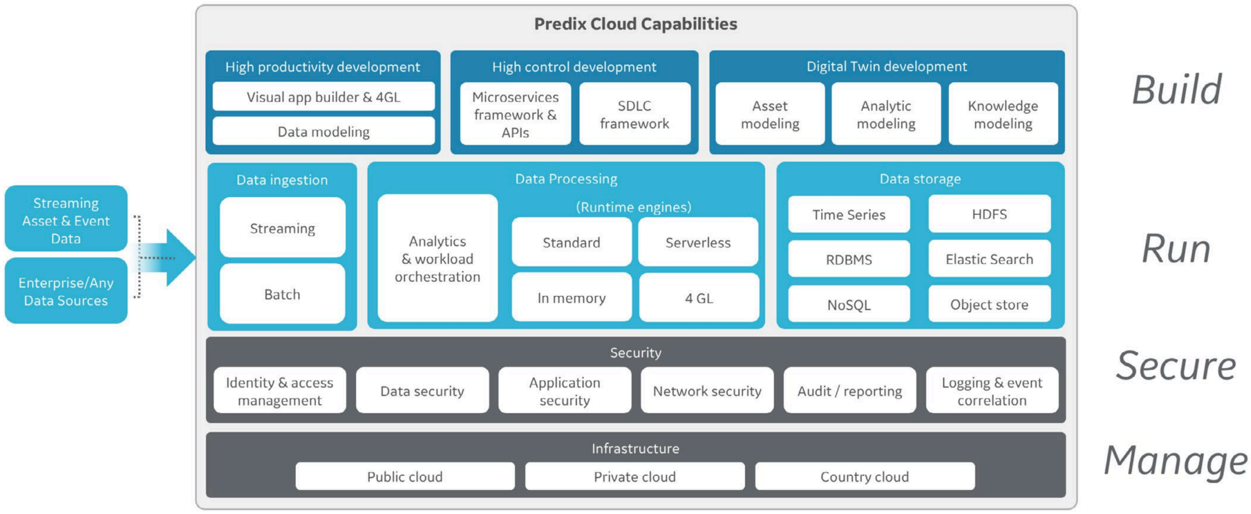

Figure 35 Predix cloud capabilities [13]

Today, GE has narrowed its scope. Predix runs on AWS and GE Digital does not offer its own cloud solution.

Platform Ecosystem

GE Digital established an ecosystem of partners for establishing Predix as an industry leader. It became a founding member of the Industrial Internet Consortium, an open membership, not-for-profit group that focused on developing use cases, test beds, sharing best practices, reference architectures, and influenced global standards development to ensure interoperability[14]. GE, along with ARRIS, CableLabs, Cisco, Electrolux, GE Digital, Intel, Microsoft, Qualcomm, and Samsung, formed the Open Connectivity Foundation. The OCF's goal was to unify IoT standards so

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[13] https://ecosystems4innovating.files.wordpress.com/2016/11/predix-the-platform-for-the-industrial-internet-whitepaper.pdf

[14] https://www.ge.com/digital/sites/default/files/download_assets/Predix-The-Industrial-Internet-Platform-Brief.pdf

that companies and developers can create IoT solutions and devices that work seamlessly together along with IoT specs, protocols, and open source projects for IoT.[15] GE Digital also partnered with Intel, Capgemini, TCS, Deloitte Digital, Infosys, Genpact, Softtek, and Wipro Limited as part of the Global Alliance Program[16]. GE Digital also partnered with multiple companies, such as Bosch, for open platform and interoperability.

GE Digital ecosystem included partners[17] in multiple roles to deliver end-to-end solutions:

- System integrators
  Industrial service providers for digital industrial transformation projects.
- ISVs
  Built value added solutions
- Service providers
  Leveraged Predix cloud and applications to deliver industrial internet services.
- Technology partners
  Led technology development and integration with the Predix platform and industrial internet technology stack
- Resellers

Figure shows the Predix ecosystem and partner value network. Initially, GE expected the partners to focus on non-GE customers. Due to the difficulties faced in the

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[15] https://www.sdxcentral.com/articles/news/ges-predix-iot-platform-attracts-developers/2016/06/

[16] https://wiprodigital.com/news/ge-digital-unveils-global-alliance-program-to-spur-industrial-internet-growth/

[17] https://www.ge.com/digital/sites/default/files/download_assets/GE-Digital-Partner-Program-2019.pdf

execution of the plans, the ecosystem strategy was changed multiple times. This approach was later changed to where GE decided to have partners focus on verticals such as mining and manufacturing adjacent to its core verticals.

[18][19][20]GE Digital has now made its ecosystem much smaller and limited to system integrators and resellers. Also, GE has been looking to work with partners more closely and to integrate them in the go-to-market strategy in the core verticals.

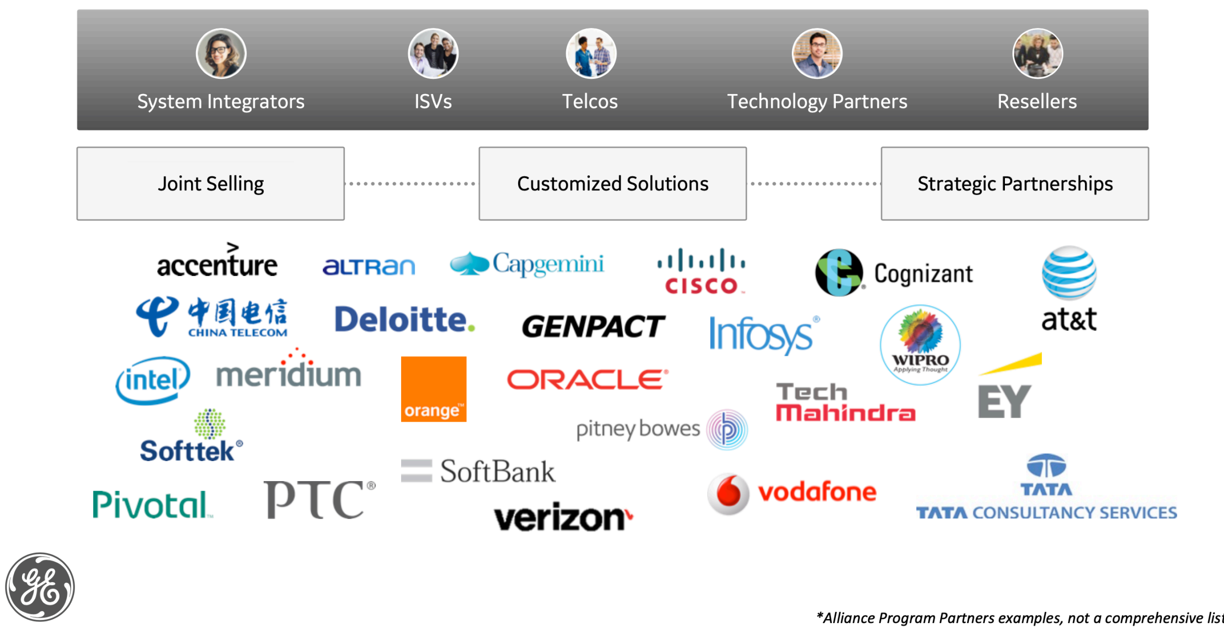

Figure 36 Predix Partner Ecosystem in 2017. [74]

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[18] https://www.crn.com/slide-shows/internet-of-things/a-year-under-pat-byrne-ge-digital-is-more-pragmatic-less-theatrical/1

[19] https://searcherp.techtarget.com/feature/GE-Digitals-transformation-rocky-but-ongoing

[20] https://www.crn.com/slide-shows/networking/300094731/ge-digital-channel-executive-no-other-company-has-built-a-partner-ecosystem-this-broad.htm/11

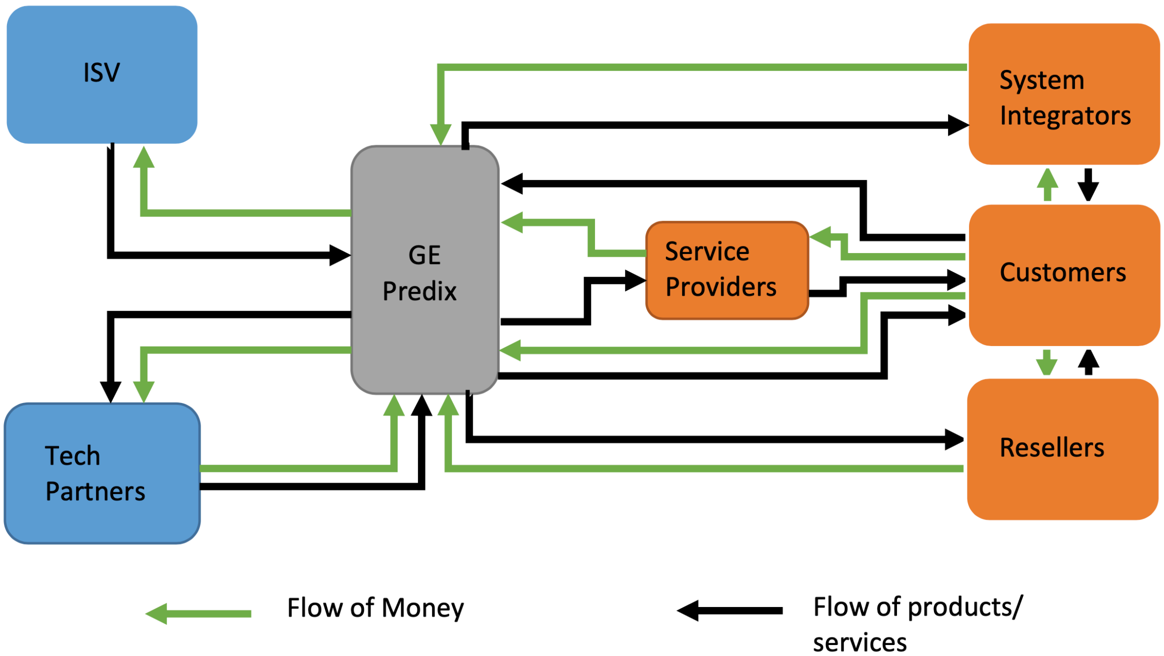

Figure 37 GE Predix platform ecosystem value network. [21]

Organization Structure

GE took a top-down centralized approach to the development of capabilities and organization. Bill Ruh was hired from Cisco in 2011 as the Vice President of GE Software. Jeff Immelt created GE Digital in 2015 with Bill Ruh as the CEO of the centralized business unit to lead the creation of digital IIoT platform. The business unit integrated GE Software and GE's operations in industrial security and information technology. Each

[21] Data source: https://www.ge.com/digital/sites/default/files/download_assets/GE-Digital-Partner-Program-2019.pdf

of the other verticals had a Chief Digital Officer, who reported to both the business unit CEO and to Bill Ruh.

In 2016, Jeff Immelt moved the headquarters to Boston, MA from Fairfield, CT to have easier access to the talent. GE Digital was located in San Ramon, CA to be closer to the talent pool in Silicon Valley.

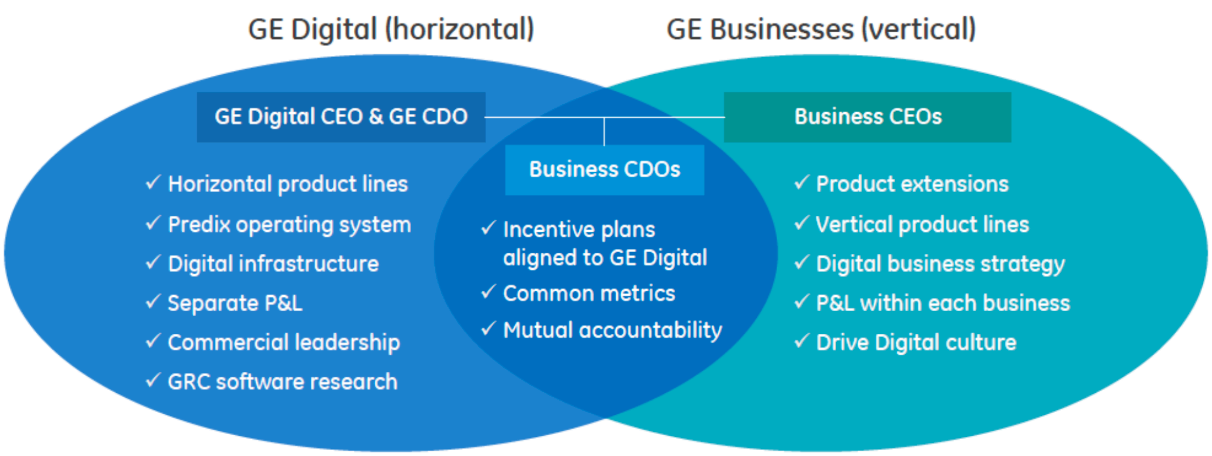

Figure 38 GE Digital Organization. [74]

Culture

Traditionally, GE was a conservative industrial company that operated in highly regulated markets with slow moving product development cycles. Work culture emphasized on getting it right the first time and reducing the risk. It would be an understatement to say that the initiative to inculcate and imbibe a faster, risk taking Silicon Valley culture was a huge undertaking. Immelt's comment that it was the most important thing he had worked on in his life underscored the importance and enormity of the task [74].

[22][23]GE promoted the 'FastWorks' approach to improve the speed of product development and other initiatives within the company. Many workshops in the 'Lean Startup' philosophy were organized for the management. GE changed the annual performance review processes to make it more continuous. Employees were encouraged to travel and interact with digital employees in San Ramon [74].

GE launched an advertising campaign to rebrand itself as an industrial digital company and to attract talent. The efforts resulted in the number of software employees reaching to 1400 in 2015 and 5500 in 2018.

Business model

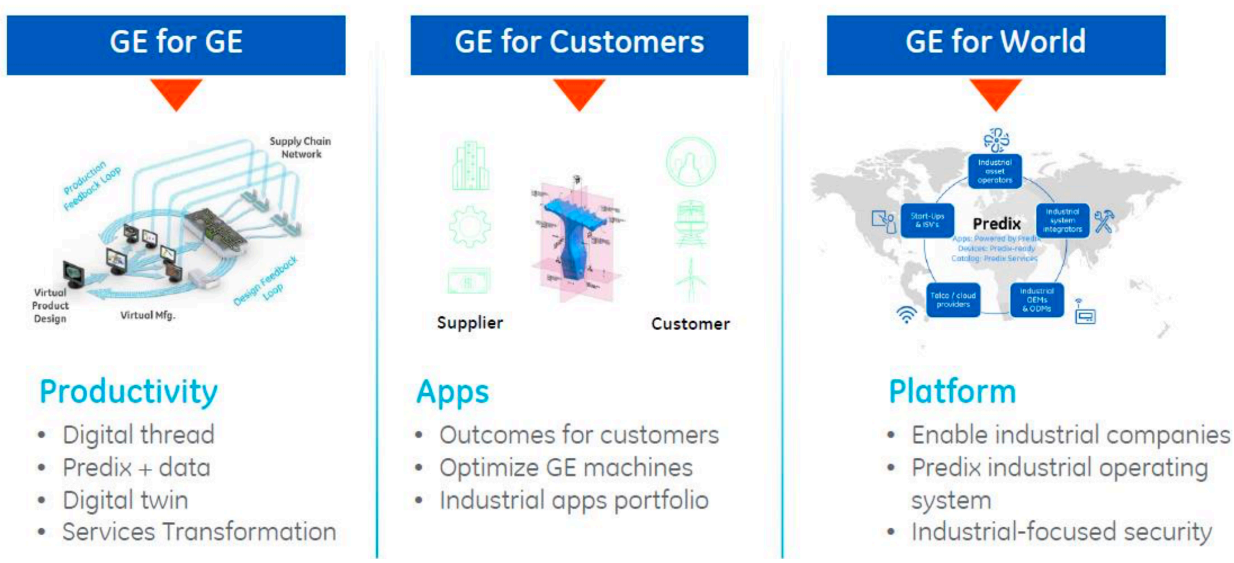

Figure 39 GE Digital Business Models. [74]

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[22] https://www.linkedin.com/pulse/fastworks-agile-project-management-long-cycle-product-rahul-wagh/

[23] https://academy.nobl.io/how-ge-implemented-fastworks-to-act-more-like-a-startup/

GE positioned its digital offerings as a PaaS and SaaS model with IaaS available to store data in GE data centers [74]. As a SaaS offering, it charged customers annual subscription for software products. It also used outcome-based payment models with a promise to generate certain value to its customers and any revenue above the threshold was split evenly with the customer. It also used enterprise deals to manage and operate large wind farms and other installations.

Market strategy

GE envisioned to build a cloud-based operating system like Android and iOS for industrial applications that could be used by anyone to plug-in their machine. The Predix platform was the focal point of the digital strategy, which positioned Predix as a general-purpose platform.

GE adopted a staged approach, wherein it would develop the digital platform in three steps- GE for GE, GE for customers, and GE for world [92]. In the first phase, GE focused

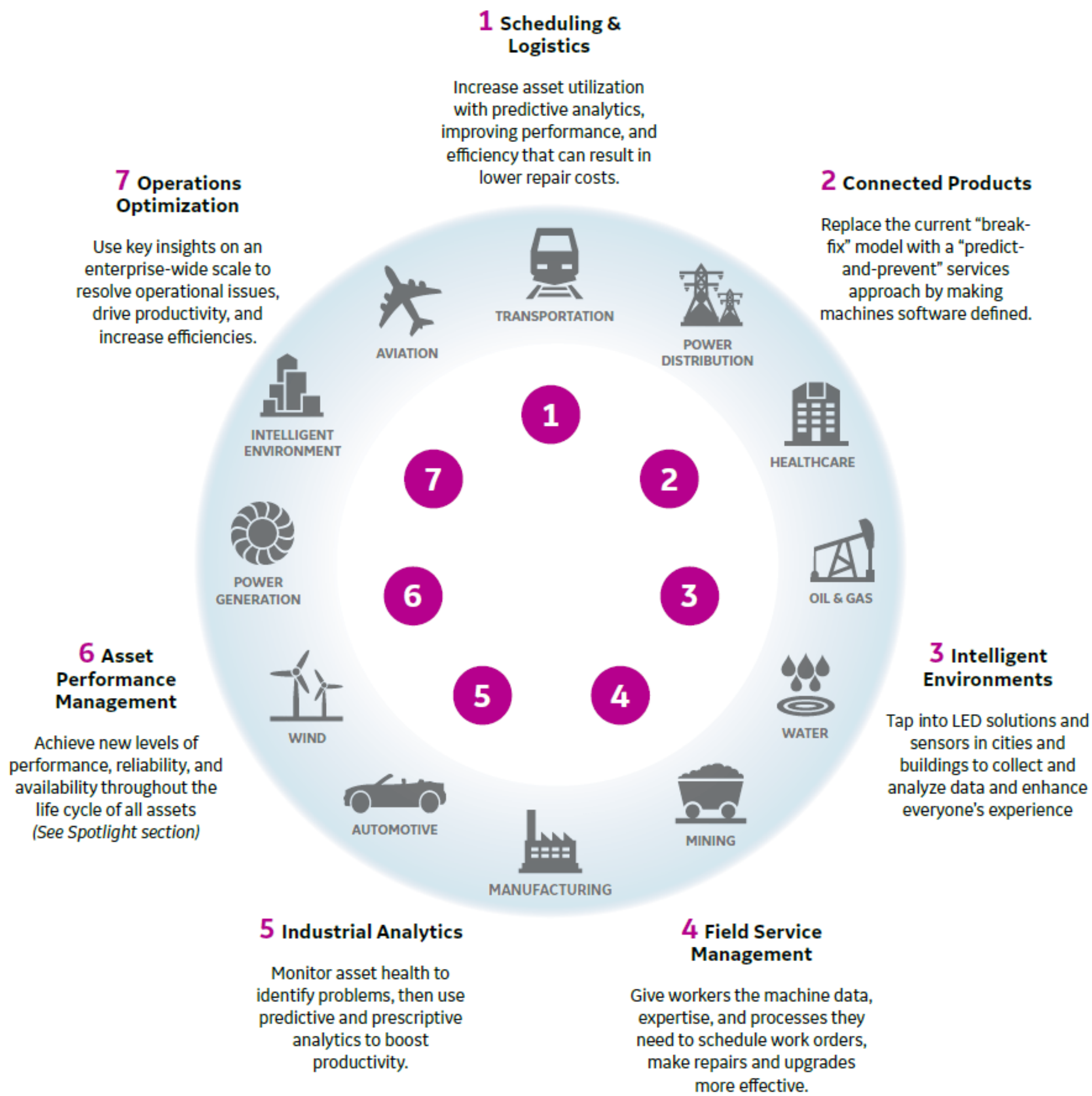

Figure 40 GE Predix platform markets and use cases. [46]

on improving productivity by digitalizing its own operations to generate gains that would be used for the next step, GE for customers. In the second step, it would offer the knowledge gained as a result of the first step to its customers as part of product offerings. In the last step, it would build a platform that could be utilized by non-GE customers, expanding its market reach.

Initially, GE defined 12 markets and 7 use cases. In the markets where it already had customers, it went alone in reaching to the customers, but allowed partners in other markets. This policy was changed in 2017 under the leadership of John Flannery, when GE Digital identified 8 core verticals where it led the go-to-market strategy and allowed partners to lead the go-to-market strategy in adjacent markets such as mining. Later it whittled down the list of core verticals to 6. Upon assuming charge in 2018, Larry Culp further narrowed the focus to 4 core verticals- power generation, oil and gas, electric grid, and manufacturing- before adding aviation to the list[24][25][26].

GE also acquired number of companies to bring in new capabilities, offerings, and access to new markets. In 2016, GE acquired Bit Stew and Wise.io to advance its data crunching and machine learning capabilities for Predix and digital twin offerings[27]. It also did acquisition of IQP, a no-code platform[28]. GE acquired Meridium, a market leader in Asset Performance Management, in 2016 for $495 million and created a joint venture with Baker Hughes. GE acquired ServiceMax, a cloud-based field service company for $915 million.

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[24] https://www.automationworld.com/factory/iiot/article/13317967/ge-orients-predix-strategy-around-key-verticals

[25] https://www.crn.com/slide-shows/networking/300094731/ge-digital-channel-executive-no-other-company-has-built-a-partner-ecosystem-this-broad.htm/3

[26] https://www.crn.com/news/applications-os/ge-digital-ceo-pat-byrne-partners-essential-for-manufacturing?itc=refresh

[27] https://www.automationworld.com/factory/iiot/news/13316367/ge-digital-acquires-more-data-intelligence

[28] https://www.linkedin.com/pulse/ge-digitals-latest-iiot-acquisition-makes-predix-its-industrial-ruh/

4.2.3 Strategy analysis

GE's Predix platform launch makes an interesting case of a platform launch by an established industrial company. It is useful to analyze GE's strategy using multiple frameworks- platform wannabe, platform leader as an established company, boundary resources and capabilities, and platform launch. Predix is still an important player in the IIoT market, but its market performance is nowhere near GE's original aspirations in terms of market share.

Predix definitely qualifies as a legitimate platform when evaluated against the criteria listed in Gawer and Cusumano's work about platform leaders [71]. It solves a technology problem for industrial customers aspiring to connect their machines to the internet and draw insights from the data for the purpose of improving productivity and profitability. Also, GE aspired to make it easy to use and connect so that it could be widely adopted.

GE seems to have struggled to adopt platform strategy as described by Gawer and Cusumano, which requires *an industry platform to be no longer under full control of the originator, even though it may contain certain proprietary elements* [71].

Drivers

GE was correct in identifying the risks posed by technology changes to its business model which relied on manufacturing and selling industrial equipment along with service contracts [93]. As data started to increase in value as compared to the equipment, GE feared losing out the services revenue to other companies. GE also saw this as an opportunity to change internal processes and enter into a high potential market.

Risks

Risks in the strategy have become clear over the years and GE has responded to them by making changes. [29]The biggest risk was a mismatch between ambition and capabilities based on skills and culture along with issues due to legacy technology choices exacerbated by the inexperience in software and platform markets and lack of skills in ecosystem development among top leadership[30]. [31]

Coring and Tipping

GE was successful at coring and developing an ecosystem to allow development of add-ons. Though, it appears to have been too successful at keeping intellectual property closed and protecting the main sources of revenue to the extent of not allowing ecosystem partners to proprietary data and access to core customers, hampering its own efforts to promote wide adoption. Being open enough and protecting core revenue generating technology and business information is a fine skill and GE seems to have failed at this where other companies like Intel and Tesla were very successful [54]. GE also did not address complementors' concerns about data privacy and fears about sharing their data with a competitor as GE was also competitor in many of the markets. [54] Gawer and Cusumano have discussed the approach taken by Intel as it formed a not-for-profit Intel Architecture Lab that operated by creating a partition between itself

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[29] https://internetofbusiness.com/ge-building-services-company-cloud-iiot/

[30] https://www.wsj.com/articles/the-dimming-of-ges-bold-digital-dreams-11595044802?mod=djemalertNEWS

[31] https://www.reuters.com/article/us-ge-digital-outlook-insight/ge-shifts-strategy-financial-targets-for-digital-business-after-missteps-idUSKCN1B80CB

and Intel, giving confidence to its complementors that their investments will not benefit a competitor.

GE was marginally successful in tipping the market as it won a good share of orders in early stages when it had limited competition and it was able to leverage its brand to win 80% of the orders that it bid for [74]. It made significant investments and signaled its seriousness and sincerity in offering a great platform [74]. GE also formed coalition with other industrial competitors to establish standards and protocols. GE also conducted hackathons and gave incentives to attract developers. GE seems to have stumbled in the execution as concerns about its real capabilities grew. [32]Customers complaints about the platform being not user friendly and about lack of support for implementation. Competition from startups and other industrial competitors grew and GE's troubles from other issues affected adoption of the platform. Interestingly, GE did not focus much on establishing interdependencies between features, envelopment, or pricing to build critical mass on the demand side.

Business resources and capabilities

Bill Ruh, GE's Chief Digital Officer, eventually hoped that Predix could become as widespread in industrial equipment as Microsoft Windows was on PCs. Bill Ruh believed that Predix can be embedded in every industrial machine that's sold [74]. Siemens and many other companies believed that a single platform for all applications and machines is not feasible [75]. It becomes necessary to understand GE's competencies and resources in light of the broad vision.

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[32] https://www.reuters.com/article/us-ge-digital-outlook-insight/ge-shifts-strategy-financial-targets-for-digital-business-after-missteps-idUSKCN1B80CB

Resource Based View theory analyzes an organization's resources and capabilities to uncover best options to leverage those assets for a long-lasting competitive advantage. GE strongly believed that having designed, manufactured, and serviced the industrial equipment it was best positioned to build the IoT platform for digitalization efforts in these industries.

The knowledge gained from industrial activities, access to market, and brand value could be considered as some of the most important assets for GE. Analyzing these using the VRIO framework, it is evident that these are Valuable, Rare, and costly to Imitate, but GE was not Organized and lacked experience to be able to capture their value in the form of a digital platform.

Though GE hired approximately 4000 employees, including 1000 software engineers, to work in the Digital business, these employees were hired from technology companies and lacked the knowledge and contacts with the traditional industrial businesses of GE[33]. The problem was exacerbated by the physical distance between the San Ramon and rest of the locations of other businesses.

Also, GE clearly lacked understanding about the scale of effort due to lack of software and platform experience at the executive level, resulting in not enough pushback and investigation of some of the decisions pushed by GE Digital to other businesses [75][34][35]. GE lacked experienced product management and salesforce personnel to work with new

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[33] https://www.crn.com/slide-shows/internet-of-things/a-year-under-pat-byrne-ge-digital-is-more-pragmatic-less-theatrical/1

[34] https://fortune.com/longform/ge-decline-what-the-hell-happened/

[35] https://www.reuters.com/article/us-ge-digital-outlook-insight/ge-shifts-strategy-financial-targets-for-digital-business-after-missteps-idUSKCN1B80CB

digital business models. Paas and SaaS business model require new sales and accounting practices. GE struggled to reconcile its industrial products business model with the new approach that was required [33].

The broad scope of the go-to-market strategy seems to have worsened the impact of these shortcomings in the organization, which was further exacerbated due to GE not encouraging the complementors in its core vertical market segments.

Analysis using the four platform leadership principles

- Scope- The initial decision of GE to implement in three stages- GE for GE, GE for customers, and GE for world –along with the decision to have complementors focus on non-core markets weakened the platform strategy. GE appropriated and kept significant value to itself, which reduced the attractiveness of its ecosystem to the complementors. It also impacted GE's effectiveness in driving the platform adoption in its core markets[36].
- Product technology- GE formed alliances with other companies and opened its technology to outside developers, though the legacy issues and the vision to have one platform for the huge variety in use cases, markets, technical needs along with legacy technology choices within GE businesses made it difficult to implement the vision and caused product technological issues.
- Relationships with external complementors- GE made attempts to generate consensus by founding and joining open alliances and using Cloud Foundry, but GE did not manage to wield a strong influence on the partners. As Cusumano and Gawer point out, to influence partners, a platform needs to sacrifice short-term gains and

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[36] https://www.reuters.com/article/us-ge-digital-outlook-insight/ge-shifts-strategy-financial-targets-for-digital-business-after-missteps-idUSKCN1B80CB

convince partners that it is acting on behalf of the whole industry. Intel did that beautifully, but GE did the opposite by discouraging partner entry into its core markets and attempting to control the entire technology stack even in areas where it could have partnered with established companies such as AWS for data centers.

- Internal Organization- The creation of GE Digital and the organization structure created a top-heavy approach. This created a disconnection with the customers and GE Digital faced problems in convincing customers about the value proposition [75].

Market launch strategy

GE seems to have made the fundamental mistake of assuming IIoT market to be similar to other operating systems, such as Windows, Android, and iOS, and positioned the Predix platform as a general all-purpose industrial operating system[37]. They assumed the market to be a winner-take-all market where a general-purpose offering will conquer the market. They failed to understand the niche markets that would have made it challenging.

GE started with 5 sides for non-core markets but discouraged their participation in the core markets. GE correctly tried to incentivize participation of developers and sponsored hackathons and tried other ways to encourage participation on the supply side. GE did not try to generate critical mass and instead went too broad by entering multiple markets at the same time. For its core verticals, GE's strategy appeared more product like than based on platform thinking. For governance, GE controlled the quality of the complementors.

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[37] https://www.cio.com/article/3142019/ge-wants-predix-to-be-the-windows-of-industrial-iot.html

4.2.4 Aftermath

After change of 2 CEOs among many other developments, GE has changed its strategy to be more application and solution centric as a SaaS player. Figure 41 and 42 show GE Digital's current digital channel and system integrator partners.

Figure 41 GE Digital Channel Partners.[38]

[38] https://www.ge.com/digital/partners/channel-partners

Figure 42 GE Digital System Integrator Partners.[39]

GE no longer has the vision to be a general-purpose platform but views it as an enabler of its solutions[40]. GE ecosystem does not have a marketplace and includes only 2 partners- system integrators and sales channel partners[41]. GE Digital focuses on 5 verticals and has a desire to work closely with partners in core as well as non-core verticals.

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[39] https://www.ge.com/digital/partners/system-integrator

[40] https://searcherp.techtarget.com/feature/GE-Digitals-transformation-rocky-but-ongoing

[41] https://www.ge.com/digital/partners/partner-ecosystem

4.3 Comparison with Siemens' approach to digitalization and launch of MindSphere

Siemens is another big industrial conglomerate and a direct competitor of GE in many of the markets. Though similar in size and legacy, their approach to digitalization and launch of IIoT platform could not have been more different. In contrast to GE (though it remains an important SaaS player), Siemens still is a IIoT PaaS market player with application marketplace and has had a positive result with its platform launch and digital transformation efforts[42].

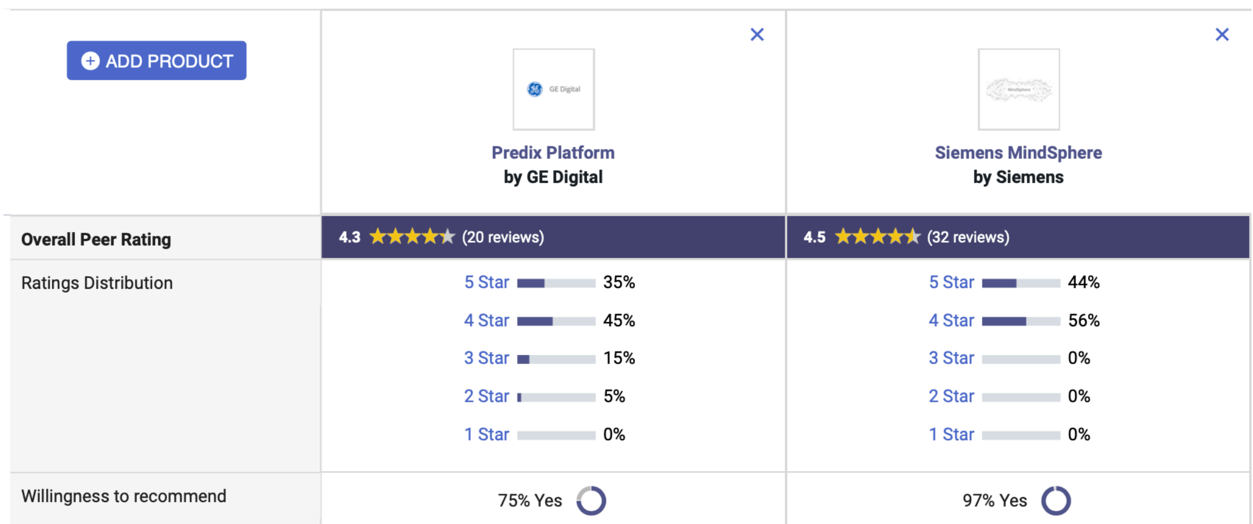

Figure 43 Customer Feedback Comparison for Predix and MindSphere on Gartner. [43]

At Siemens digitalization was declared as a top priority in 2014 when Siemens' CEO Kaeser announced Vision 2020 to set the strategic direction for the company with a mission statement: *"We make real what matters by setting the benchmark in the way*

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[42] https://www.barrons.com/articles/siemens-digital-transformation-is-picking-up-steam-the-stock-jumped-6-51611322481?siteid=yhoof2&yptr=yahoo

[43] https://www.gartner.com/reviews/market/industrial-iot-platforms/compare/product/predix-platform-vs-siemens-mindsphere

we electrify, automate and digitalize the world around us. Ingenuity drives us and what we create is yours. Together we deliver."[44]

Market strategy

In contrast to GE, Siemens' management believed that one offering would not be able to work with the diversity of needs in different IIoT applications. For example, CEO of Siemens' Digital Factory division, argued, *"To believe that you can use for a hospital the same thing as for some milk-processing company or automotive manufacturer is a bit farfetched."* GE made the mistake of underestimating the differentiated needs in the market and positioned the platform as a general-purpose industrial operating system.

Product technology

The MindSphere platform was more modular than Predix and was designed with a core that could be built on by individual businesses according to their needs. This also avoided building a complex general-purpose platform as a single solution to all different markets. Siemens already had digital service and data analytics solutions and MindSphere was intended to work with internal divisions and with external customers.

Resource Based View

In contrast to GE that had aimed to be a top 10 software company by 2020[45], based on its revenue from software products, Siemens would have already qualified as a top 10

[44] Tarkian, Sophia. "The digital transformation of Siemens." MSc diss., 2019.

[45] https://www.zdnet.com/article/ge-forms-ge-digital-aims-to-be-top-10-software-company/

software company in 2017[46]. Siemens had strong software capabilities as it employed 17000 software engineers and 220 data scientists in 2015 as part of its various software businesses that operated in PLM and other areas. Siemens was no stranger to the challenges of developing software offerings and it could be said that their executive leadership was more familiar with these challenges than that of GE [75].

Ecosystem

Siemens planned to make the platform interoperate with IBM, Accenture, and SAP. [47]Siemens was also more open and willing to work and share with ecosystem partners. MindSphere relied on AWS right from the time of its launch. [48]One of the presentations of MindSphere AWS offering quotes the MindSphere architecture team as saying- *"We don't want to manage anything we don't have to manage."* The same presentation has the VP of MindSphere products saying- "We want to ride AWS's innovation curve, not fight it." Siemens setup an innovation fund with Atos to fund the software platforms and ensured accountability towards targets. This approach was in contrast to that adopted by GE.

Governance

Siemens made sure that they kept focus and remain customer centric. One Siemens' CTO is quoted as saying, *"We had to understand where scale is the winning argument*

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[46] https://www.linkedin.com/pulse/siemens-bets-big-software-all-across-ag-monica-schnitger/

[47] https://d1.awsstatic.com/events/reinvent/2019/Building_on_AWS_The_architecture_of_the_Siemens_MindSphere_platform_MFG202.pdf

[48] https://d1.awsstatic.com/events/reinvent/2019/Building_on_AWS_The_architecture_of_the_Siemens_MindSphere_platform_MFG202.pdf

versus where customer intimacy is the winning argument [75]*."* Another executive is quoted as saying, *"The triggering point must always be the customer challenge that you want to resolve, and what is the best, most efficient, quickest way to resolve it. That should be the guiding question, ideally using as many corporate synergies as possible. But when corporate is just driving everything centrally, you risk disconnecting business units from the customers."* Siemens setup user group called MindSphere World in participation with partners to set data related rules and share resources. One example of the differences in the customer approaches between the two companies is the on-premise offering. Siemens offered on-premise data storage right from the start based on the customer concerns about privacy, but GE offered them only much later in 2018 after initially believing that central cloud based offering is the right solution despite customer demands to the contrary.

Executive leadership

Contrast between the top decision makers at the two companies would make for an interesting comparison. Kaeser had worked at Siemens all his career and was known as a pragmatist with understanding of Siemens' capabilities and culture[49]. At GE, Immelt too had worked at GE most of his career and had a reputation as someone who believed in the GE way, taking the execution capabilities at the company for granted. Bill Ruh was an outsider and did not have prior connections and understanding of other GE business units.

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[49] Tarkian, Sophia. "The digital transformation of Siemens." MSc diss., 2019.

Execution

Siemens took a more decentralized approach which was driven by the business units based on their needs, whereas GE setup a central GE Digital business unit for the digitalization purpose [75]. Siemens adopted a collaborative pull approach with a committee in charge of the ground-up Siemens Digitalization Program and included the CTO and nine divisional CEOs (as opposed to GE's push approach where GE Digital was the direction setter) with business units and worked closely with them to ensure that their needs were met with and the implementation was effective. Also, each business CEO had the responsibility to help other businesses that were behind in their progress, making it a team effort.

Siemens' digitalization initiative did not have a separate P&L responsibility as opposed to GE Digital, which had a set revenue target for 2020. It skewed GE's efforts towards short term profit booking and GE had to take out the $3 billion revenue contribution due to double booking. Often the digital initiatives resulted in conflicting priorities for the business units as it affected their performance due to a mandate to use the Predix platform that many times was inferior to the software used by these individual divisions within GE.

Table 1 Comparison of GE and Siemens IIoT Strategy.

	GE	Siemens
Number of customers	[50]21000	[51]1100
Devices	NA	1.3 Million
APIs	51	36[52]
Applications		400[53]
Partners	1000	[54]500
Clouds	AWS, Azure	SAP HANA, AWS, Alibaba, Azure, IBM, Red Hat
Number of sides	3 (6[55])	7
Chicken or egg strategy	Subsidized developers	Subsidized developers
Network effects	Low	Low
Business model	SaaS and PaaS[56]	SaaS, PaaS (IaaS for existing customers)

[50] GE does not provide information about distribution and definition of who they consider as customers

[51] https://www.iotworldtoday.com/2019/06/07/siemens-exec-dishes-on-mindsphere-industrial-iot-platform/

[52] https://developer.mindsphere.io/apis/index.html

[53] Building on AWS: The Architecture of the Siemens MindSphere Platform https://d1.awsstatic.com/events/reinvent/2019/Building_on_AWS_The_architecture_of_the_Siemens_MindSphere_platform_MFG202.pdf

[54] https://www.prnewswire.com/news-releases/siemens-mindsphere-continues-industrial-iot-momentum-301000526.html

[55] Reduced from the original 6 sides that includes user base.

[56] GE has limited its PaaS offering with the platform offered only to the current customers.

Openness	Owns algorithm	Ownership of data and algorithm ambiguous; Open platform
Organization	Separate BU with P&L	Initially embedded in other BUs and no P&L
Current Focus	Solutions focused	Open platform at the heart of digital transformation software suite

5. Learnings and Market Launch Guidance

This chapter lists the learnings from GE and Siemens case analysis and extends it further to platform launch strategy decisions by introducing a new concept of market ecosystem, which is a cluster of markets with strong indirect network effects due to interdependencies.

It describes the selection of bottleneck markets using Input-output model. The bottleneck market selection guidance is supplemented by guidance for market ecosystem design by selection of initial side markets to generate indirect network effects along with a platform positioning framework by estimating the future competition among IIoT platforms, which could also be adopted by platforms in other areas.

Previous works have explored the concept of bottlenecks and their control with modularity and system architecture as a driver of competitive advantage. This section uses some of the findings from platform theory about the research on network effects and their impact on winner-take-most markets and market competition along with concepts in marketing and economics.

5.1 Learnings

- It is extremely important to analyze the market and the expected competition to position the platform and decide the subsequent strategy.

  GE Digital positioned the platform as a general industrial operating system for all industrial equipment, which proved to be a huge mistake as the market became very competitive with low network effects and high customization needs of the customers. Siemens focused on use case approach and differentiated the platform.

- Initial markets in which the platform is launched should be carefully selected so that it gives competitive advantage to the company.

  GE Digital, adopting a horizontal strategy, entered 8 verticals that did not have significant indirect network effects among them. Ultimately, they had to narrow down to 4-5 verticals.

- Markets that require considerable customization and technical development should avoid horizontal strategy by focusing on use cases to deliver early value and adopting a vertical or hybrid strategy using a highly modular design.

  Siemens successfully adopted this strategy by designing a highly modular platform that could be customized by each business unit based on their needs. GE Digital's platform was ahead of the times in its vision, but it did not anticipate the difficulties due to lack of standards with a high degree of customization.

- Organizational structuring and internal practices are extremely important for employee participation and its effect on focus of customer needs. Be prepared to update your internal sales and accounting practices too.

  As GE found out late, top heavy centralized structure with a separate BU could lead to distance from customers. Siemens correctly adopted a grounds-up strategy that made sure that individual BU needs were addressed, leading to a cohesive organic strategy. PaaS and SaaS require changes in sales and accounting practices.

- Having leadership with software development experience and understanding of challenges about software development projects along with digital product development resources is very important for digital transformation success.

  Siemens' internal software resources and experience due to its PLM business could be seen as a significant reason for success of Siemens' strategy. GE's lack of software development experience at the leadership level proved to be a hindrance in correctly assessing the risks and choosing between options.

- It is important to have focus and let customer needs and use cases drive the development in digital transformation. The lack of focus could result in wastage of resources which could be better utilized in adopting new technologies in a fast-changing field.

  GE Digital tried to boil the ocean instead of winning beachhead segments. GE tried to be present across and maximum capture value the stack and value chain leading to loss of focus and resources for new technologies such as VR and 5G-private cloud, ServiceMax, external consulting, data centers. Siemens was laser focused in its execution, leading to accountability and significantly positive results.

- Early P&L responsibility could lead to short term goals and effective measures need to be designed that the right priorities are considered.

  Software BU served internal customers for digitally enabled services, product upgrades as GE double counted $3 billion revenue, losing focus of digital transformation. In contrast, Siemens, sold the SIS business to Atos and setup a JV for IT.

- It is extremely important establish trust with customers and partners.

GE Digital faced slow adoption as GE was considered a competitor, GE data was not shared with third party developers, and data ownership was an issue with some customers due to privacy concerns [99]. GE owned the algorithm. Siemens in contrast allowed on-premise solution.

- Platforms adopting horizontal strategy should consider launching them as independent companies as they have high capital requirements, making it easier to raise resources.

  GE's problems influenced GE Digital. GE underestimated the capital, resources, and capabilities required for a digital platform and a spinoff would have helped

5.2 Platform Launch Decision Guidance

GE Digital vs Siemens' comparison highlighted the importance of selecting the right markets to enter and getting the market positioning strategy correct. GE Digital struggled because it brought a horizontal strategy to a market that required vertical or hybrid strategy. This section provides guidance to correctly assess the appropriate strategy requirement of a market based on the potential competition and to design the market ecosystem by selecting the bottleneck market as a primary market along with other markets with strong localized indirect network effects and high commonality.

Market launch strategy consists of three important decisions- markets in which the platform is launched, positioning in these markets, and timing of entry. Some of the concepts from adjacent fields such as economics and marketing could be combined with recent research in IIoT markets and platform thinking to propose a new market launch recommendation for platforms.

Based on the platform positioning, the platform positioning strategy could be classified as:

- General positioning
- Differentiated positioning

Based on number of markets that platform is competing and positioning of the platform, platform strategy can be classified as:

- Vertical strategy- the platform competes in only a few markets that may not have much commonality.
- Horizontal strategy- the platform competes across a number of markets.
- Hybrid strategy- the platform competes in a select few markets with commonality and possibly strong indirect network effects.

This section discusses some of the concepts related to bottleneck markets that are found in various field, Input-Output model in economics, and multisided platform design to propose a process for market positioning along with market ecosystem design and strategy selection. This section discusses the basics of these concepts and brings them together to make process recommendations. It makes three specific process recommendations:

1. Bottleneck market selection.
2. Platform positioning framework.
3. Market ecosystem design by selecting markets for simultaneous launch of the platform.

Bottleneck markets and platform design

Network theory emphasizes the importance of control points or high-density nodes that connect with other nodes. This concepts of controlling the nodes or bottlenecks of a network finds applications in many areas. Jacobides and MacDuffie discuss ways to drive value towards the focal firm [87]. Gawer and Cusumano discuss the strategy adopted by Intel to control the technical standards for connectors in the architecture, driving competition downstream and securing its leadership position [54]. Pagani finds that profits and competitive advantages reside at the control points in the value networks by analyzing three broadcasting industry models- closed vertically integrated, loosely coupled coalitions, and multi sided platforms [85]. Supply chain bottleneck were discussed by Mizgier, Juttner, and Wagner [77]. Baldwin discusses the concept of bottleneck in technical systems, industry architectures, and their relations with modularity and system boundaries [78]. Ida discusses the concept in relation with network industries [79]. Similarly, the concept of bottleneck has been discussed in value chains by Henkel and Hoffman [79] and by [80] Jacobides, Knudsen, and Augier in relation to industry architecture, where they extend the work done by Teece [81]. This work extends the understanding further and applies it to the market launch problem faced by ecosystems.

In its essence, the concept can be distilled as understanding the interdependencies among the entities and exploiting them by solving a bottleneck problem and controlling the solution to collect rent from other entities connecting with the bottleneck entity and using the solution. The entities could be technical systems or firms in a value chain or markets in an ecosystem.

Critical mass, Path dependency, and Indirect network effects in IIoT multi-sided platform design

Much work has been done in network multi-sided platform ecosystems. Network platforms achieve equilibrium and take-off with critical mass of adopters. Thus, it is important to reach critical mass as soon as possible.

An important characteristic of network markets is path dependency, which means that the success of the network in reaching critical mass is dependent on its history. One way of doing so is launching in a smaller market and reaching critical mass. It is comparatively easier to drive adoption in a smaller market with strong localized network effects. Facebook adopted such a strategy when it initially launched at Harvard and subsequently expanded to other campuses before opening up to other users. Such a strategy also allows for gradual addition of features and capabilities to new users and markets and is suitable for IIoT platforms with a large market of users with differentiated needs that require customized solutions.

Multi-sided platform ecosystems exhibit direct and indirect network effects as discussed in section 2.3, providing increased benefit to the users when more same-side or cross-side users join the platform. The indirect effects could be based on complementarity between products that have increased benefits when used together by the same user or between different products used by different user groups. Network effects economics give rise to special pricing schemes that allow one product to be subsidized for increased adoption and more value to be captured in other product markets with positive network effects due to increased willingness-to-pay of those customers as discussed by Parker and Van Alstyne [20]. Hagiu states that, exhibiting indirect network effects is a necessary condition for true multi-sided platforms and gives two criteria for designing a feature or functionality in a multi-sided platform that it needs *to reduce search cost, incurred by the MSP's multiple constituents before transacting, and reducing shared costs incurred during the transactions themselves* [19]. Hagiu states that *the general principle regarding shared cost reductions is to include only those functionalities which are sufficiently "horizontal", i.e. which benefit a wide enough range of the MSP's constituents* [19].

Some of the other work done by [68] Lee, Lee, and Lee, [79] Zhu and Iansiti, and [78] Zhu and Iansiti point to the effect of indirect network effects on the competition in the industry, entry into platform markets, the resultant industry structure, and the defensibility of such ecosystems. Greater the network effects, greater is the probability of one or two companies capturing most of the market with a winner-take-most outcome. Increased network effects also make the platform's market share and position difficult to dislodge.

Input-output model and bottleneck markets

An Input-output model is a model in economics that shows the interdependencies and trade between different industries for any given region [88] [89]. Because it is data of transactions between the industries there is overlap and the same good may have undergone multiple transactions. Even so, useful information can be derived from the data to understand the industries that produce the most output for each unit of spending.

Figure 44 shows the network graph plotted in Python with pyvis interactive data visualization library using the Input-Output data provided by the Bureau of Economic Analysis with connections between major industries in the US economy. As it can be seen, Manufacturing industry is strongly connected with Construction, Agriculture, and Mining and could be selected as the bottleneck market. Similar data could be collected and plotted at a finer level for industries or sectors by further breaking down the national level data to understand the interdependence of markets that a platform or company is interested in entering.

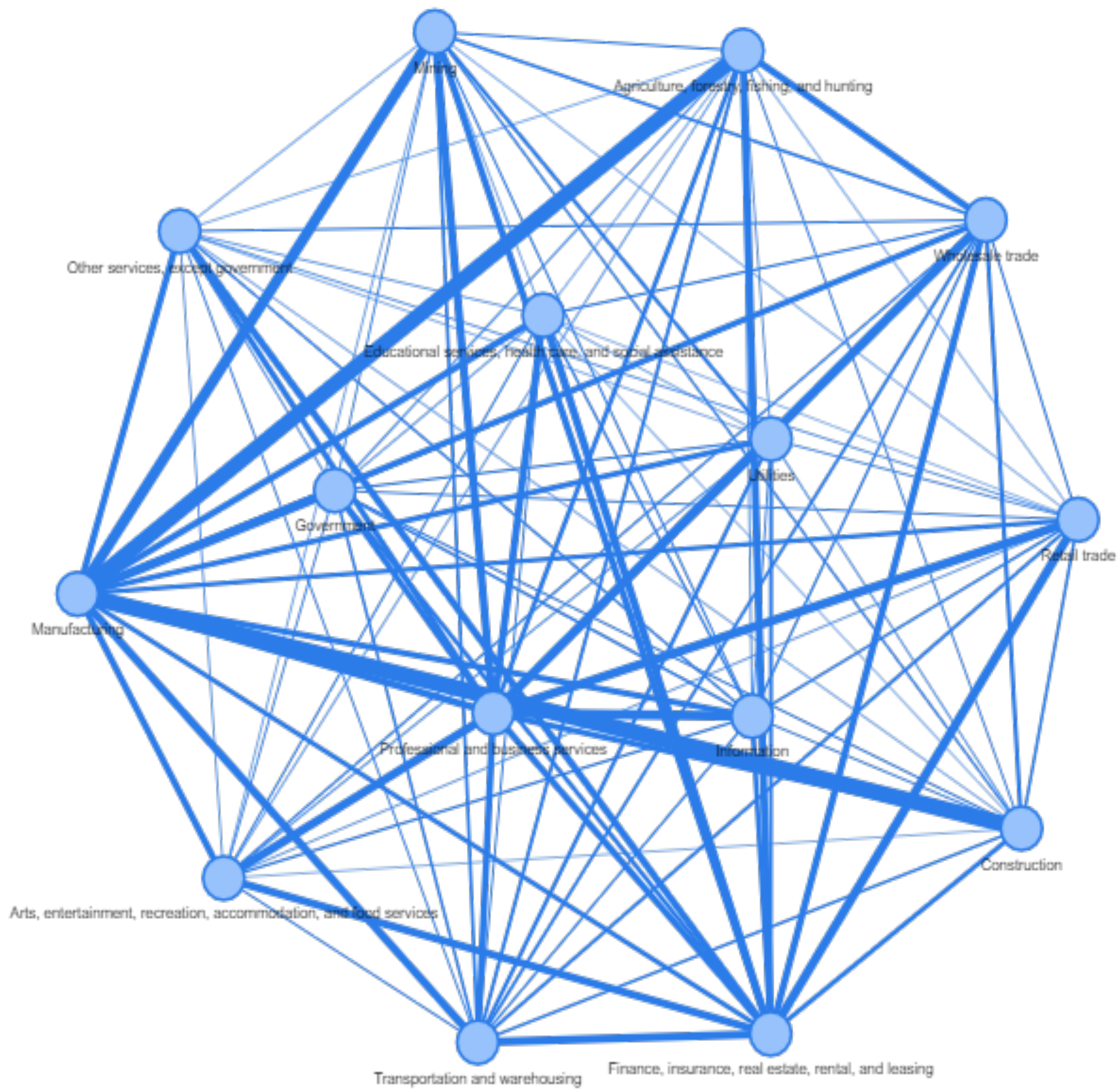

Figure 44 Input-Output Model Network. [57]

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[57] Data source https://apps.bea.gov/iTable/iTable.cfm?reqid=52&step=102&isuri=1&table_list=10&aggregation=sec

Value chain, value network, and horizontal integration of IIoT Solutions

New technologies help overcome the inefficiencies between interactions at interfirm transaction level, one of the main reasons for vertical integration of firms, leading to the development of distributed supply chains. Internet and digital IIoT is a key enabler of this trend. Nagy et al., discuss the value of IIoT for value chain of a firm [80]. Rayport and Sviokla consider virtual value chains as important as regular value chains [82]. Porter and Heppelmann discuss the effects of connecting products and the resultant productivity and efficiency gains [91].

PwC survey lists the efficiency gains that can be obtained by horizontal integration between suppliers and various partners in value networks beyond organizational boundaries as an important use case for Industry 4.0 applications [81]. The value or supply chain network consists of the OEM and tier 1, tier 2, and tier 3 suppliers. Operating a successful supply chain consists of integrating different processes in all the participants to gain real-time visibility and efficiencies.

Companies in a supply chain network exhibit strong interdependencies in their activities and connecting them through an IIoT virtual value chain to give real-time visibility in customer demand and other dependencies presents a strong value proposition.

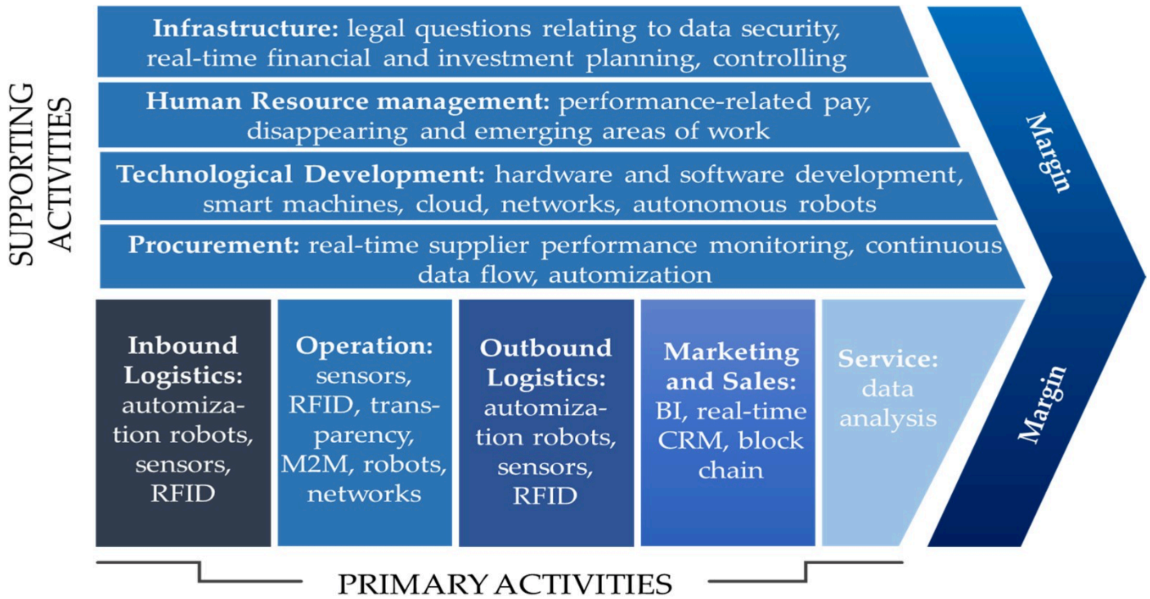

Figure 45 Value Chain Model with IIoT Technologies. [58]

Industry platforms, product platforms, and market ecosystems

Product platforms exist within a firm to drive commonality, and reducing costs using economies of scope. Robertson and Ulrich discuss the distinctiveness and commonality trade-offs for product platforms [84]. Market ecosystem could be described as a network of markets with strong network effects anchored by a bottleneck market, which is selected as described in the 'Input-output model and bottleneck markets' section on page 98. The markets in the market ecosystem have strong indirect network

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[58] Nagy, Judit, Judit Oláh, Edina Erdei, Domicián Máté, and József Popp. "The role and impact of Industry 4.0 and the internet of things on the business strategy of the value chain—the case of Hungary." Sustainability 10, no. 10 (2018): 3491.

effects with the bottleneck market and possibly with each other. Other works have discussed ways to find adjacent markets based on value chain analysis[59][60]. This work uses input-output model to find adjacent markets to the bottleneck market with strong network effects to build a market ecosystem that a platform can use to launch with a hybrid strategy.

For the design of market ecosystem, industry platforms can also be shown to have the characteristics of product platforms. The extant literature treats these two types of platforms differently and there has not been much discussion about architecture trade-offs for industry platforms on the market strategy. This work helps in extending the understanding of industry platforms and shows congruence between industry platform and product platform concepts for market ecosystem design and platform launch.

Horizontal vs vertical IIoT platform strategy

Schermuly et al. discuss the trade-off between horizontal strategy vs vertical strategy for IIoT platform developers [83]. Their finding based on industry survey shows that IIoT customers prefer focused project-based approach as against the preference of platform owner who prefer a horizontal generic platform that allows reuse of resources for economies of scope, reducing the development cost. A hybrid staged strategy is recommended by the authors.

This question also becomes important in consideration of selecting markets to launch the platform. Similarity between initial markets helps to reduce the development costs.

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[59] https://oleg-81036.medium.com/how-to-find-new-markets-through-value-chain-analysis-ff8b9d74c065

[60] https://www.nfx.com/post/10-years-about-market-networks/#:~:text=What%20Is%20A%20Market%20Network,other%20people%20in%20the%20network.

In this aspect, the product platform approach becomes important to consider and finds applicability in industry platform theory.

Proposition

An industry platform should select a bottleneck market as the primary market for launch along with other coupled markets to design a market ecosystem so that they give rise to strong localized indirect network effects. The selection of markets should be considered against the commonality of features between the markets and the resultant marketing, product development, manufacturing, logistics, and service (value chain) costs.

5.2.1 Platform positioning framework

Using the concepts discussed earlier in this work, a decision framework is synthesized to help in platform market launch decisions for platforms owners. The decision framework provides guidance for market positioning of platforms.

As a first step, the market under consideration is assessed to determine whether it is a winner-take-most market based on the criteria listed by Eisenmann, Parker, and Van Alstyne [62]. If it meets the three criteria of strong network effects, homogenous user needs, and absence of multi-homing, the platform should adopt a general positioning with horizontal strategy. Inability to meet these conditions, signals a fragmented market with significant competition.

If the criteria for winner-take-most is not met, the platform owner may consider entering upstream or downstream of the technology stack/ virtual value chain. For example, owners considering entering IIoT platform may be better off, given the high competition, competing as a SaaS applications and solutions provider. Incidentally GE and few other IIoT platform owners are now changing their initial PaaS strategy to adopt this approach and position as a SaaS provider.

If the owner intends to compete in the market under consideration and the answer to the previous question about upstream or downstream markets is no, as a next step, the risk of multi-homing is checked. In the presence of multi-homing, a platform may be better suited to adopt a differentiated strategy.

Next, presence of differentiated needs and strength of network effects is assessed. If these conditions are met, the platform owner should consider selecting a bottleneck market and adding new sides to strengthen the indirect network effects.

The redesigned market with new sides and stronger network effects should be assessed again for winner-take-most conditions. A final selection is made after 2-3 iterations.

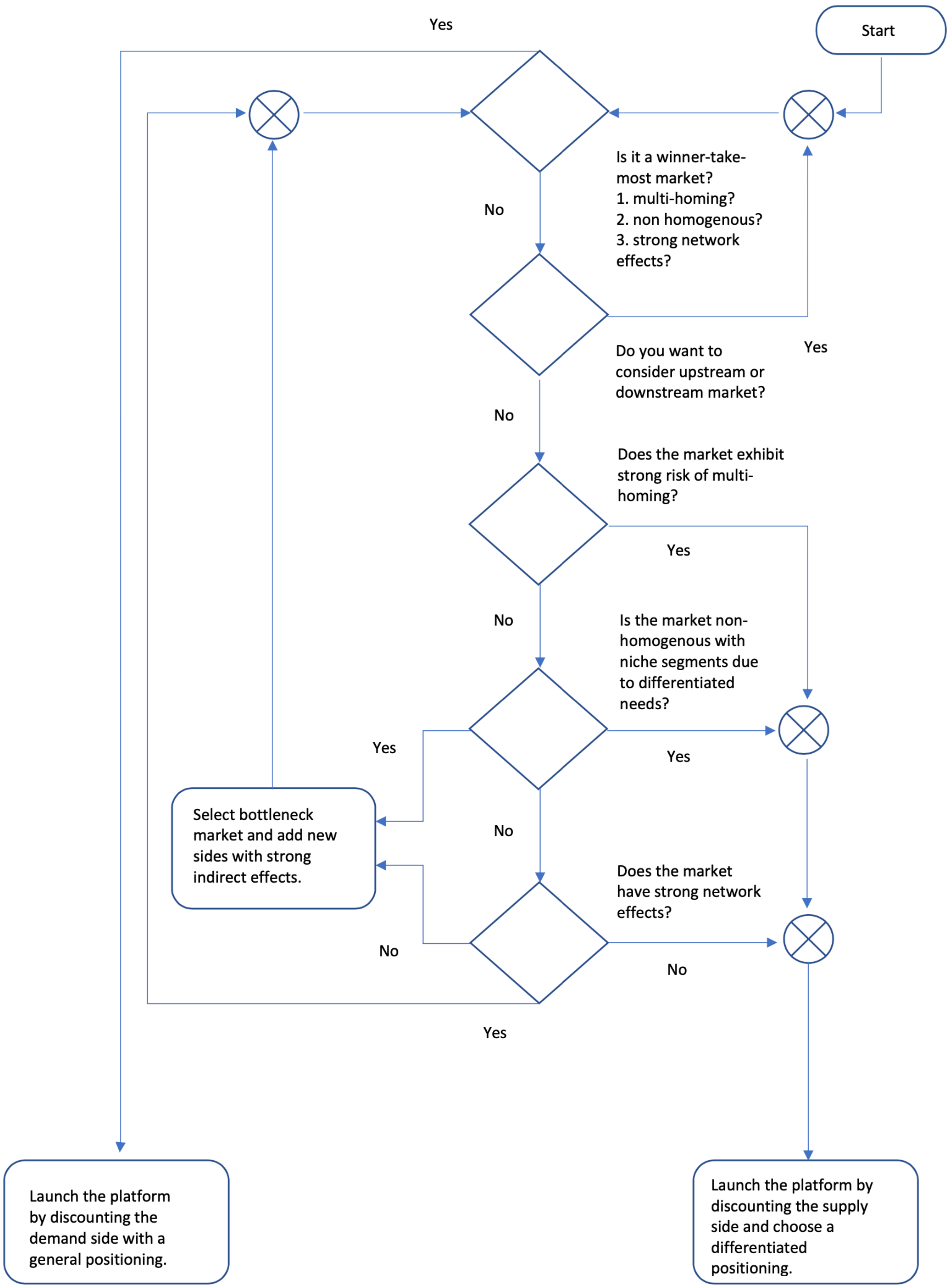

Figure 46 Market Positioning Framework.

5.2.2 Platform launch market selection

For a successful launch strategy, the markets in which platform is launched should be carefully selected so that they enable the platform to reach critical mass. Selection of market as a part of market ecosystem should be based on the pull or indirect network effect exerted by the bottleneck or anchor market on the given market and commonality of the given market with the bottleneck market.

Commonality between two markets is the reduction in costs due to similarity in product design, manufacturing, architecture, and market similarity resulting in lower costs of market launch. Based on the literature about product architecture and marketing, if two markets are similar the cost required to launch platform in that market is lower.

Similarly, if two markets have strong network effects, the increase in revenue of the given market increases the revenue of the bottleneck market and vice versa.

Modeling the value of ecosystem

The market selection and ecosystem design at platform launch problem could be interpreted as value maximization of market ecosystem for variable number of markets/ sides problem. An optimization model for selection of markets to maximize the value of the market ecosystem for platform launch is described in this section.

For a true network offering which is only used to connect with other users, let i be a potential market segment, with $i \in (1,2)$. Let P_i be the price in market i and R_i be the estimate of potential revenue in market i obtained by selling quantity q_i at the estimate of potential cost C_i.

For two markets market 1 and market 2, R_{12} be the additional revenue in market 1 due to indirect effects α_{12} of market 2 and R_{21} additional revenue in market 2 due to indirect effects α_{21} with market 1. Let c_{12} be the total commonality between the two markets. Let Π_1 be the potential estimate of profit in market 1 and Π_2 be the potential estimate of profit in market 2. Total profit is equal to the sum of profits due to direct effects in all the markets and the profit due to indirect effects. The estimate of potential total profit of a platform operating in markets 1 and 2 is:

$$\Pi = \Pi_1 + \Pi_2 \qquad \text{(Equation 1)}$$

$$\Pi = (P_1 q_1 + \alpha_{12} P_1 q_1 - C_1) + (P_2 q_2 + \alpha_{21} P_2 q_2 - C_2) + C_{12}(C_1 + C_2) \qquad \text{(Equation 2)}$$

The expression for profit between two markets could be generalized for i and j by replacing 1 and 2 with i and j respectively.

$$\Pi = \left(P_i q_i + \alpha_{ij} P_i q_i - C_i\right) + \left(P_j q_j + \alpha_{ji} P_j q_j - C_j\right) + C_{ij}(C_i + C_j) \qquad \text{(Equation 3)}$$

where, $C_{ij} = C_{ji}$

Expression for maximum profit for n markets in a market ecosystem can be written as:

$$\Pi = \max_{i \neq j} \sum_{i=1}^{n} \sum_{j=1}^{n} [\left(P_i q_i + \alpha_{ij} P_i q_i - C_i\right) + C_{ij}(C_i)] \qquad \text{(Equation 4)}$$

Thus, it can be seen that maximum estimate of potential profit can be obtained by entering in markets with strongest indirect effects and most commonality.

Selecting markets for simultaneous entry at launch with hybrid strategy

Bottleneck market is selected by plotting the input-output model of the markets of interest as described earlier. The framework in Figure 46 provided guidance for differentiated and general positioning of the platform. This is further developed to provide guidance on selection of new sides, for the design of market ecosystem, that have strong indirect network effects and commonality with the bottleneck market. As described earlier, commonality between two markets is the reduction in costs due to similarity in product design, manufacturing, architecture, and market similarity resulting in lower costs of market launch.

Other markets that form a market ecosystem with the bottleneck market can be selected based on the guidance in this section. Selection of markets to enter at launch is to be based on the value added by indirect network effects and commonality as modeled in Equation 4. The model developed above could be used recommend a process for selection of markets in the market ecosystem by maximizing the value of estimated profit.

The indirect network effects between a market under consideration and the bottleneck market add value to the market ecosystem around Market 1 (bottleneck market). Value added by the markets in the market ecosystem where the platform is launched simultaneously can be plotted against the markets under consideration to show their individual contribution and to select the most valuable markets. It will depend on the strength of indirect network effects and the reduction in costs due to commonality.

Three cases can be considered based on the variation in indirect network effects and required customization and the resultant single-market or multi-market entry strategy:

Single market or vertical strategy (Scenario 2)

In this scenario, bottleneck market does not have indirect effects with other adjacent markets or has little commonality with considerable customization required. Vertical single market focused strategy is best in such a case. There is no value added from indirect effects with adjacent markets and all the value comes from the bottleneck market, i.e. Market 1, as seen in Figure 47, and the optimum number of markets to launch the platform is close to 1 in a truly vertical strategy.

Multi-market strategy

1. Horizontal strategy (Scenario 3)

   When indirect network effects are strong and evenly distributed, the platform can launch as a horizontal platform in many markets. The required customization for each market is less and the commonality curve is flat with considerable commonality and cost reduction between markets. The relative value addition by each market to the bottleneck market could be obtained by using the Metcalfe's law (by dividing the value of the total network, which is proportional to N^2, by the number of nodes N) [5]. Social networks like Facebook would be a good example of such a scenario. The value added by all the markets is substantial, as seen in Figure 47, and the optimum number of markets lies to the right end of the plot.

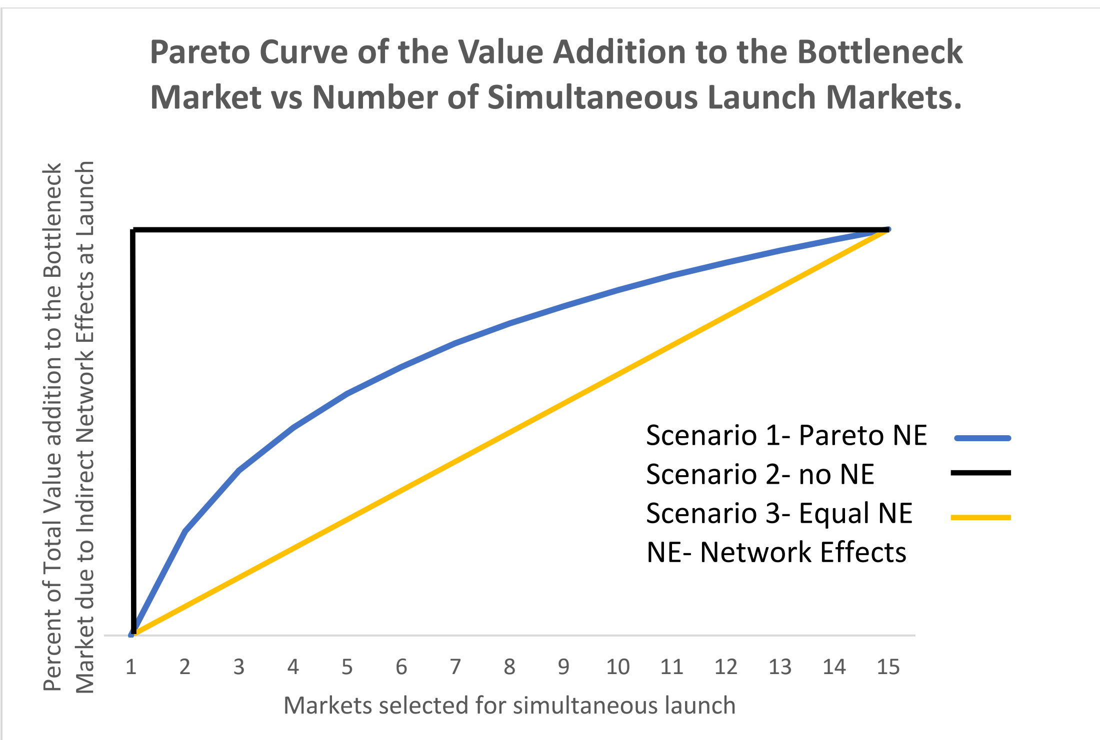

Figure 47 Cumulative Distribution of Value Added with Indirect Network Effects to the Bottleneck Market as a Function of Market Sides at launch.

Figure 47 shows the variation of value added due to indirect network effects between the bottleneck market and other markets at launch. X axis shows the number of markets a platform enters simultaneously at the time of launch.

2. Hybrid strategy (Scenario 1)

   In most of the real-world cases where network effects are localized, indirect network effects are unevenly distributed. When network effects are concentrated among a few markets and weak among the rest, it requires careful selection of markets based on the strength of indirect network effects with the bottleneck market. The relative value addition by each market to the bottleneck market could be obtained by using the Zipf's law (by dividing the value of the total network, which is proportional to N*log(N), by the number of nodes N) [5]. A few markets add most of the value as seen by the pareto curve in Figure 47, and the optimum number of markets for simultaneous launch would be typically with ~3 markets.

   In a hybrid strategy, the markets that the platform enters at launch should be selected such that they have high indirect network effects and low customization to generate critical mass and benefits from the optimization.

The overall logic of selecting number of markets to launch will follow these steps-

1. Select few (~10-15) markets of interest. (For example, manufacturing, transportation, utilities, retail, healthcare, construction, etc. in the case of IIoT)

2. Choose the bottleneck market (by plotting the network graph as in Figure 44, which I plotted in Python using the Bureau of Economic Analysis data), which is Market 1.

3. Plot estimated value addition due to indirect network effects (Figure 47) and cost reduction due to commonality (Figure 48) graph between Market 1 and the remaining markets.

4. For each market, sum the value addition due to indirect network effects and cost reduction due to commonality.

5. Arrange remaining 9 markets from most value adding market to least value adding market on the X axis.

6. Plot the cumulative value distribution against number of markets at launch using the data obtained from step 5.

7. Select the inflection point of the plot, which is the pareto point. Ideally, a platform would want to be in as few markets as possible to reduce investment and capture maximum value.

Figure 48 shows the cost reduction due to commonality between the bottleneck markets and other markets at launch. In many real-world cases, there is considerable commonality between few markets, but the curve drops off quickly when more markets are considered. X axis shows the number of markets a platform enters simultaneously at launch.

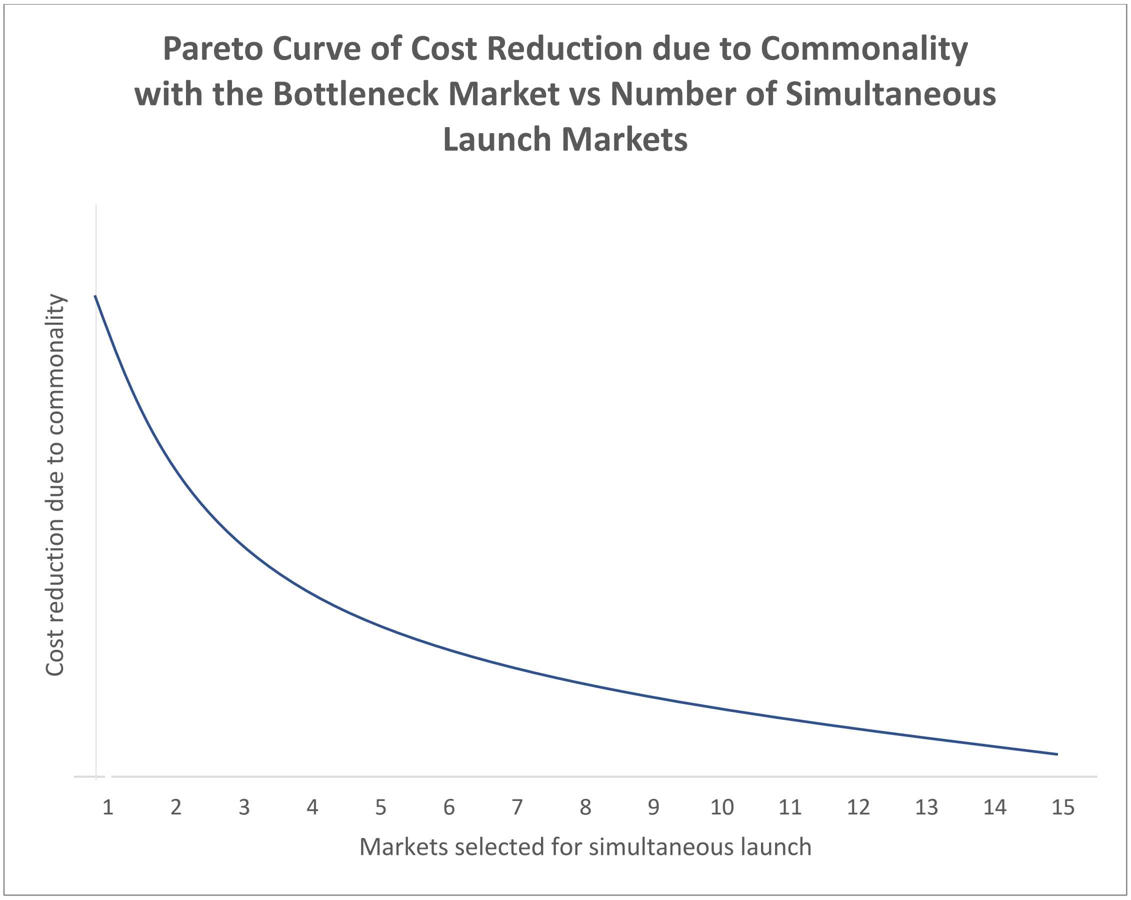

Figure 48 Variation of cost reduction due to Commonality with change in number of Market Sides for simultaneous launch.

5.3 Managerial Implications

Value of the ecosystem is maximum for a platform with an optimized number of markets, which varies depending on the variation of the strength of network effects and commonality in a market ecosystem.

For vertical segments with no indirect network effects and high customization, a vertical market launch strategy works best in increasing the value of the ecosystem.

For mild indirect network effect markets with commonality new sides with stronger indirect network effects could be added such that, few markets add most of the value to the launch strategy as given by pareto (20:80) principle. Thus, a hybrid market launch strategy is best for mild and concentrated indirect network effects market. IIoT markets are suitable for hybrid strategy [83]. Some of the mobility platforms, such as Uber, are adopting this strategy to generate indirect network effects by adding new sides, such as Uber Eats, (though they are targeting the same customer in contrast to the discussion earlier where each market side has a different user).

For markets with high connectivity behavior with substantial value addition due to indirect network effects by all markets and low customization, a horizontal strategy is the best. Operating systems, such iOS and Android, social networks, such as Facebook, are good examples where horizontal strategy is suitable.

It is significantly important to understand the market network effect strength and adopt a suitable strategy as wrong ecosystem design can have significant negative effects as seen in the case of GE Digital.

6. Conclusion and Recommendations

This work reviews the platform and IIoT literature and applies it to the cases of GE Digital's Predix and Siemens' MindSphere platforms. The two platforms are compared for number of characteristics, such as design and architecture, market strategy, and execution along with supporting elements, such as internal resources and leadership. The study draws important lessons from the comparison that would be useful for the launch of digital IIoT platforms.

The study contributes to theory by converting the market selection in platform and ecosystem design problem into a value maximization problem. The work converges the industry platform and product platform approaches, which have so far been dealt with individually, for the selection of markets.

The lessons drawn are generalized and the study makes useful contributions to the managerial understanding by drawing the attention to the importance of correct assessment of potential competition and further providing guidance framework for positioning of the platform by estimating the competitive environment based on the strength of network effects, differentiated user needs, and multi-homing in the market. It also provides guidance for the important topic of platform and market ecosystem design by recommending a process for selection of bottleneck market along with other related markets, which is gaining importance in the face of increasingly crowded platform market as many new platforms are being launched with increased awareness of the topic.

1.1 Future Work

The work done for platform launch market selection could be developed further to compare the outcome for pioneer and follower platforms. Also, the positioning framework in 5.3 could be expanded to consider the effect of factors, such as amount of technical development work required for pioneer platforms, on the competition and the strategic outcomes.

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