

The Strategic Path and Countermeasures for Building Huawei's HarmonyOS Ecosystem

-- A Theoretical Reference based on the Historical Lessons of NEC PC-98

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Abstract

To pursue technological self-reliance, Huawei launched fully native HarmonyOS in response to external technology supply cutoffs. The system breaks away from Android and achieves independent core technology. But it also faces multiple challenges. To examine how non-compatible strategies affect the operating system ecosystem, this article adopts a case study approach. It takes the PC-98 system of Nippon Electric Company (NEC) in the late 1990s as a historical reference sample, rather than a horizontal comparison, to review the reasons behind its rise and fall and to analyze HarmonyOS's current difficulties and potential risks. The study finds the following. First, the core of NEC's decline lay in misjudging closed incompatibility as a long-term moat, and Japan's shift in industrial policy from "support" to "laissez-faire" accelerated its collapse. Second, the core of HarmonyOS's current predicament comes from an incompatible strategy. It needs to face its long-term challenges. Third, the key to operating system ecosystem competition is developer competition based on business value, and HarmonyOS must complete the transition from being "policy-driven" to "profit-driven". Fourth, full-scenario interconnection and the AI revolution create a strategic window for HarmonyOS. But the window is time-sensitive, so the ecosystem leap needs to be achieved within a limited period. Drawing on the lessons of the PC-98, this article proposes optimization strategies that balance compatibility, coordinate developers and policies, pursue phased global rollout, and evaluate strategy dynamically. The study makes clear that real competition in operating systems is ecosystem competition. At its core, it is a contest for developers. The article argues for moving beyond extreme closure, for balancing independent innovation with open ecosystems and policy support with market forces, and for seizing the window for transformation. It also warns against path dependence and ecosystem collapse.

Keywords

NEC PC-98; Huawei HarmonyOS; Ecosystem Building; Incompatibility Strategy; Developer Ecosystem.

1. Introduction

1.1. Research Background

In 2019, the U.S. added Huawei to its Entity List. Google stopped licensing GMS services, and Huawei's overseas mobile phone business faced a supply crisis. External sanctions forced Huawei to accelerate the launch of HarmonyOS, long regarded as a "strategic backup". October

2024 saw the release of native HarmonyOS NEXT, which removed AOSP code and the Linux kernel, dropped Android APK support, and worked only with native HarmonyOS apps.

A deeper tension runs between technological autonomy and ecosystem independence. Sanctions brought HarmonyOS to the fore, but the rush toward "pure native" development also demands that the app ecosystem make up years of ground in a short window. The decision to cut Android compatibility entirely left native HarmonyOS facing a cluster of problems at once, as tooling, developer adoption, app migration, user retention. External pressure gave rise to HarmonyOS and its independence, yet that same pressure now makes ecosystem building harder, with no established model to follow.

Operating systems can trigger ecosystem crises through their compatibility choices. NEC's PC-98, a computer system that dominated Japan from the 1980s into the 1990s, is a textbook case. Launched in 1982, the PC-98 parlayed first-mover advantage and closed standards into years of market dominance, its share peaking above 50%. Then the ground shifted. IBM Japan introduced DOS/V, which broke down language barriers, while Dell and Compaq flooded the Japanese market with low-cost compatible machines. A fierce price war followed. The decisive blow came in 1995, when Windows 95 arrived with compatibility for both PC-98 and general PC architectures, its unified API wiped out the very advantages on which PC-98 had built its position. Market share collapsed from 60% to 33% within five years. By 1997, NEC had phased the system out entirely.

The history shows that operating system competition is fundamentally ecosystem competition, and compatibility strategies shape the direction of platform network effects. The rise and fall of the PC-98 also carries a warning for native HarmonyOS.

1.2. Research Objectives

- (1) The PC-98 declined because it was incompatible with global standards. What can that history teach Huawei, which is now pushing hard to build the HarmonyOS ecosystem?
- (2) What was the key mechanism behind PC-98's failure? How did the incompatibility decision lead to the collapse of its ecosystem?
- (3) What lessons from the PC-98 can guide HarmonyOS as it adjusts its compatibility strategy, develops its ecosystem, and sharpens its strategic awareness?
- (4) How do Huawei and NEC compare in their external environments? And from a business standpoint, does government support raise the risks for HarmonyOS?

1.3. Research methods

This article adopts a case study approach. It examines the PC-98, a platform that has run its full course, to trace how its incompatibility strategy shifted from a competitive barrier into a development trap. The findings offer a strategic reference for HarmonyOS.

This article treats the PC-98 and HarmonyOS as separate cases rather than as a direct comparison. It traces the PC-98's rise and fall. From that history, it draws out patterns in operating system development that hold across technology eras. These patterns serve as early warnings and practical guidance for HarmonyOS, which is still developing, rather than as a direct comparison between the two.

2. The Decline of the PC-98 and Its Causes

2.1. The Decline of the PC-98

Japanese-language support was the wall that kept foreign competitors out of Japan's PC market. Then DOS/V took it down. Any standard IBM PC-compatible machine could now handle Japanese. NEC's technological edge was gone. Windows 95 arrived in 1995 with a unified API that erased the differences between hardware platforms, and the PC-98's decades-old software

library was no longer irreplaceable. Cost pressures came from two sides: Compaq's low-price campaign from 1992 and Fujitsu's large-scale price war in 1995, both adding to the already high cost of the PC-98. Market share fell from over 60% at its peak to less than 30% within a few years. The one-time leader of the Japanese PC market was finished. Production stopped in 1997, and the platform was withdrawn.

2.2. Root Cause Analysis

2.2.1. Strategic Level

NEC misread what its strengths actually were, and it misread the industry's entry barriers as well. That misreading drove the company's decline. A closed architecture, incompatible with global standards, gave NEC temporary protection at home. It was not a durable competitive advantage. West and Dedrick (2000) examined the PC-98's unusual rise and fall. Their study shows how victory in a standards competition can be undone by a new architectural layer that bridges two or more previously incompatible architectures. Windows 95 was one such layer. It connected the PC-98 and general PC platforms, and its unified API undercut the network effects of the PC-98's exclusive software library. Within five years, the PC-98's market share fell from 60% to 33%. NEC was eventually forced to abandon the platform and adopt global standards^[1]. NEC repeated a familiar pattern. It chased short-term gains, held to its own private standards, refused to connect with global systems, and focused entirely on the local market. Compatibility and global strategy were set aside. Its compatibility decision rested on a fragile premise: a closed market with no alternatives. Once DOS/V and Windows 95 removed the local adaptation barriers and brought standardized products into Japan, the protective wall that had once shielded the PC-98 turned into a fatal weakness. The isolation of its exclusive architecture became clear, and that strategic error cost the platform its long-term viability.

2.2.2. Organizational Level

The theory of path dependence was systematically explained by David (1985) in his classic paper. He used the QWERTY keyboard as an example to show the lock-in effect in technology choices: early seeming random choices become self-reinforcing through technology linkage, economies of scale, and the quasi-irreversibility of investments, locking the market into a specific standard, making it hard to switch even when better alternatives appear later^[2].

The PC-98 brought NEC hefty profits for more than a decade. That record shaped how the company thought. When market share began to shrink, NEC's management did not reconsider its strategic direction. It tried to hold the status quo through short-term tactical moves. The bigger problem was the missed window. From the launch of DOS/V in 1990 to the widespread adoption of Windows 95 in 1995, NEC had at least three to five years to transform.

Farrell and Saloner (1985) studied standardization, compatibility, and innovation. They argued that the network effects and compatibility benefits of standardization can lock an industry into outdated standards, even when better alternatives exist, because switching is hard to do voluntarily. This is known as "excess inertia"^[3]. In situations of incomplete information, companies tend to stick to the status quo because they can't be sure if the competitors will switch at the same time, which keeps the whole industry stuck with old standards. NEC's leadership was caught in this very mechanism, held back by the historical success of the PC-98, never willing to acknowledge the limits of their closed approach. This mix of cognitive dissonance and asymmetric information caused NEC to miss the last chance for transformation.

2.2.3. Ecological Level

The PC-98's industry ecosystem looked solid, but it was a passively locked system. It rested on technical incompatibility and commercial exclusivity, not on genuine developer recognition or active loyalty. This is the core underlying reason why its ecosystem collapsed so quickly. Jacobides, Cennamo, and Gawer (2018) pointed out when developing the ecosystem theory that

the core of an ecosystem lies in "non-generic complementarities"-meaning that the investments participants make around the core platform can't be redeployed elsewhere, and this interdependence creates a deep connection that goes beyond market contracts^[4].

Ecosystems that lock users in through technical barriers are fragile. They lack both risk resistance and user loyalty. Once Windows 95 set a global standard and the PC-AT platform could handle Japanese, the wider global market, lower adaptation costs, and larger business gains became hard to resist. Developers shifted to the universal platform and left the PC-98 ecosystem behind. This really highlights the core rule of operating system ecosystems, a great digital ecosystem isn't built by tech barriers, exclusive agreements, or market monopolies to force binding. Instead, it thrives on an open platform, sustainable business value, and broad growth prospects, attracting the developers to invest and cultivate it over the long term. Closed ecosystems that lock people in can only stay prosperous for a short time, and once a better alternative comes along, they quickly collapse and disappear.

2.2.4. Policy Level

In terms of policy, the Japanese government's industrial policy played an external institutional role of "support first, let go later", indirectly but significantly affecting the fate of the system. In the 1980s, through a series of protective industry laws, the government restricted foreign investment and focused on promoting the development of the computer hardware industry, creating a greenhouse-like institutional environment for PC-98 to establish a closed standard and achieve a monopoly in the domestic market. However, in the early 1990s, when the language barriers and the software monopoly of the PC-98 were broken, the government's policy shifted from "protective intervention" to "competitive laissez-faire". Under the "creative knowledge intensification" strategy, continuing to support a closed PC standard disconnected from global standards no longer fit the country's goal of building a technology-driven nation. The government neither introduced administrative measures to force the continuation of the PC-98 standard nor gave NEC any special protection to help it transition, instead choosing to let the market decide the winner in the standards competition. This shift in policy from "support" to "letting go" sped up the elimination of the PC-98 by the global standardization wave, leading it to go from industry dominance to total collapse in just three to four years after 1995.

3. The Real Challenges of Huawei's HarmonyOS

3.1. The App Ecosystem's Double Gap in 'Quantity' and 'quality'

Ecosystem scale and app quality are still HarmonyOS's biggest weaknesses. Native HarmonyOS apps and meta-services together have passed 400,000, enough for basic needs. Android and iOS each offer millions. A smaller app pool means narrower platform coverage, and narrower coverage makes it harder to serve what users actually need.

App quality in HarmonyOS ecosystem shows a structural pattern. Basic apps are covered, high-end apps are weak, and scenario-specific apps are largely absent. Most major internet apps have only basic adaptation, and their functionality, responsiveness, and service synchronization lag behind the Android and iOS versions. Deep customization and exclusive service features are also thin. Coverage of niche and specialized apps is worse still, with many small tools and vertical-market applications not yet adapted for HarmonyOS. These gaps affect everyday use for consumers, business users, and industry users alike, and they hold HarmonyOS back from moving beyond "usable" toward genuinely polished.

3.2. The User Switching Cost Caused by Incompatibility

Under compatibility, Android users can move to a HarmonyOS device without replacing their apps or reconfiguring services. In a purely native HarmonyOS system, that changes. Paid apps,

local data, account services, and app permissions from the original Android device no longer carry over. Users have to download, adapt to, and purchase all kinds of apps and services, which takes a lot of time and money.

When choosing an operating system, consumers ask whether the apps they need are available and whether their data carries over. System performance and architecture matter less. What matters more is whether apps run as expected and whether data moves without friction. Because switching costs are high, many existing users hesitate to move to a pure HarmonyOS device. That incompatibility limits user growth, which in turn weakens the platform's network effects.

3.3. Structural Barriers to Globalized Services

Service cutoffs tied to geopolitical sanctions have put structural obstacles in front of HarmonyOS as it expands globally. In this respect, it resembles the PC-98. That system was confined to its home market and closed off from the wider world. Since the U.S. entity list took effect in 2019, Huawei devices have lacked GMS support. GMS is the baseline for Android phones sold outside China, and overseas users depend on it heavily.

In China, HarmonyOS can rely on native services and a Chinese app ecosystem to meet user demand. Outside China, no equivalent service suite exists. As a result, HarmonyOS phones sold abroad lack not only apps but the core services that mainstream users depend on. Without a service ecosystem, these devices struggle to enter major overseas markets such as Europe, Southeast Asia, and Latin America, and they remain largely confined to China. That outcome carries a risk of Galápagos syndrome—a market isolated from global standards—much as the PC-98 remained tied to Japan and missed the global PC market.

3.4. The Strategic Tension between Tech Independence and Ecosystem Compatibility

A fully independent technology strategy serves long-term security. It reduces reliance on Android, supports the development of domestic intellectual property, and aligns with China's push for technological self-reliance. The costs, however, are equally clear. Developers face higher adaptation costs, users face a harder transition, and globalization becomes more difficult. Suarez (2004) proposed an integrated framework for the competition over technological leadership in the IT industry, which further reveals this dynamic process. The fight for tech dominance happens in stages, and during each stage, the relative importance of factors like technological superiority, user base, and availability of complementary products keeps changing^[5]. If HarmonyOS cuts off Android compatibility before its ecosystem matures, it risks a deadlock. Users stay away because apps are missing, and developers hold back because users are too few. Relying too long on a compatibility layer creates the opposite problem, delaying native app growth and pushing full independence further out. Resolving this tension requires more than an either-or choice. It requires a practical balance—and here the PC-98 case offers a cautionary lesson.

4. Conclusion, Insights, and Suggestions

4.1. Conclusion

Operating system development and ecosystem building sit at the center of China's push for technological self-reliance. The choices made by leading firms shape the direction of the industry. They also carry structural, long-term risks. Historical cases can help clarify underlying patterns, current bottlenecks, and possible paths forward. This article adopts a two-case comparative framework. It first examines the PC-98, tracing its rise and fall to identify the general logic of competition in the OS industry. It then turns to HarmonyOS, still evolving, and

compares its strategic choices and ecosystem challenges with those of the PC-98. The main conclusions are as follows.

First, a closed and incompatible technology strategy carries substantial long-term risks, and shifts in industrial policy can bring those risks forward. The PC-98 illustrates this point. Specialized, non-universal standards can create exclusive market barriers in the short term and help a company secure regional dominance. But short-term monopoly gains cannot offset the systemic crisis that long-term isolation eventually produces. An operating system's compatibility strategy shapes how its ecosystem evolves, and external policy changes often trigger the collapse of closed barriers.

Second, the ecosystem challenges HarmonyOS now faces largely stem from its decision to break with mainstream ecosystems. After HarmonyOS NEXT dropped support for AOSP, several structural weaknesses became clear. Apps are limited in both number and quality, developers see weak commercial returns, users face high switching costs, and global services are absent. These problems are not unsolvable. But they show that a strategy built on independent innovation must acknowledge the gaps in ecosystem building and recognize the long-term difficulties an incompatibility strategy creates.

Third, competition among operating system ecosystems is ultimately a contest for developers, and that contest turns on commercial value. The PC-98's decline shows what happens when a closed ecosystem relies on technical barriers alone. It cannot sustain commercial appeal. Once a stronger alternative appears, developers leave. HarmonyOS therefore has to move beyond a policy-driven launch toward a profit-driven cycle that can sustain itself.

Fourth, cross-device connectivity and the AI-driven transformation have opened a window for HarmonyOS to move ahead of its competitors. Suarez (2004) proposed an integrated framework for the competition over technological leadership in the IT industry, which further reveals this dynamic process. The fight for tech dominance happens in stages, and during each stage, the relative importance of factors like technological superiority, user base, and availability of complementary products keeps changing. Opportunities in the industry are open to all market players at the same time. Google and Apple are already expanding their reach into seamless connectivity and AI operating systems, and new standards and ecosystems will form quickly. HarmonyOS must move from "usable" to "good" and then to "essential" within a limited window. Otherwise it risks repeating the PC-98's failure.

4.2. Strategic Insights

4.2.1. Incompatibility Has Never been a Moat, it's Always a Double-edged Sword

The PC-98's incompatibility with global standards drove both its rise and its fall. Once language and system compatibility barriers fell, the isolation that had sustained the platform became a liability. Hardware updates lagged, software support thinned, and adaptation costs rose. Against the global shift toward standardization, the PC-98 could not compete. The lesson is twofold. Even firms that align with global standards are not guaranteed leadership in the operating system industry. But a local OS that breaks completely from mainstream standards is far more likely to be displaced as the industry moves on.

4.2.2. The Developer Ecosystem is the Only Moat

The PC-98 ecosystem collapsed once developers stopped supporting it. In three to four years, it went from near-total market control to a failing business. Its position was overturned faster than any hardware upgrade or technology cycle could explain. Market share, technical advantages, and brand barriers are only surface strengths. What sustains an operating system is the software ecosystem developers keep building. A monopoly without developer support is fragile, and its prosperity is illusory.

4.2.3. Be Careful of 'successful Experiences' Becoming a Strategic Burden, and Also Watch out for 'policy Support' Turning into Institutional Dependence

NEC's decade-plus monopoly with the PC-98 bred a fixed internal belief that closed, proprietary standards were the best path. When DOS/V and Windows 95 disrupted the industry, that belief became a liability. Past success made the company slow to respond and reluctant to change course, and it missed the window for transformation. Japan's early protectionist policies for the domestic computer industry reinforced the same tendency. Policy support can create conditions in which a company's strategic alertness gradually erodes.

4.2.4. Don't Underestimate How Pressing the Time Window is

Once general PC standards had taken hold, developers and users had already moved elsewhere. NEC could not recover, even by recognizing the problem, cutting prices, or attempting a transformation. The lesson is that competition in the operating system market tends toward a winner-takes-all outcome that is difficult to reverse. Firms must complete their strategic shift and build their ecosystem before the industry landscape settles. Missing that window means losing market competitiveness permanently.

4.3. Strategy Suggestions

4.3.1. In Terms of Compatibility Strategy

A completely incompatible path carries high risk, because the platform must bear the full cost of ecosystem development on its own. If external conditions change, incompatibility can shift from a barrier into a constraint. This article recommends a layered compatibility strategy for HarmonyOS. For core legacy scenarios such as smartphones, it is advisable to retain transitional compatibility or bridging mechanisms, so that users are not driven away by missing apps before the native ecosystem matures. In newer areas-multi-device collaboration in the IoT, or intent-based interaction with AI agents-the aim should be to build differentiated experiences, so that incompatibility is justified by what HarmonyOS can do and Android cannot. The real test of a compatibility decision is not whether the system is fully autonomous, but whether developers and users actively choose HarmonyOS.

4.3.2. Developers and Policy

Ecosystem building now needs to shift from policy-driven to interest-driven. Yet only about 30% of registered developers are active, which suggests a gap between attracting developers and retaining them. The PC-98 case shows that relying on policy support can dull a company's strategic vigilance, and HarmonyOS should avoid a similar support dependency. The rapid growth of the HarmonyOS ecosystem has drawn heavily on policy support and emotional appeal. China's sustained policy investment aims to give HarmonyOS the time and room it needs to overcome the initial difficulties of ecosystem building. The regulatory sandbox mechanism also shows that policy can keep supporting the ecosystem while retaining flexibility for timely adjustments, so that support does not turn into excessive reliance on a single enterprise or technology path.

This article recommends that Huawei should move fast on developer incentives. The revenue share needs to beat Android's, and developers need to see real gains on HarmonyOS. A dedicated technology innovation fund would lower the early risks for small and mid-sized developers adapting to the platform. So would a clear visibility mechanism, one that helps high-quality apps gain exposure and users. Only when developers recognize that HarmonyOS is profitable will the ecosystem shift from a policy-driven launch to a benefit-driven cycle that sustains itself.

4.3.3. Globalization Layout Level

The absence of GMS poses a real obstacle for HarmonyOS overseas. Yet globalization remains the only route to economies of scale for any operating system. This article proposes a three-

phase strategy. In the near term, HarmonyOS should concentrate on the Chinese market, drawing on policy support and domestic demand to build a base strong enough to sustain itself. In the middle phase, it can move into emerging markets-Southeast Asia, the Middle East, Latin America-where GMS dependence is lower, using cost-effective products and localized services to gain a foothold. In the long run, the goal is a global ecosystem that works across devices without GMS. When users choose HarmonyOS for seamless multi-device collaboration, the absence of GMS becomes a difference to adapt to, not an obstacle to overcome.

4.3.4. Strategic Assessment Level

The PC-98 declined largely because of strategic inertia. NEC, confident after early success, held to a closed approach and missed the window to shift toward open standards. This article recommends that the HarmonyOS team establish a formal strategic self-reflection mechanism, with clear stage-based assessment points for any incompatible strategy. Taibi-Voigts et al (2025) conducted a systematic review showing that path dependence is common in innovation ecosystems, and its negative effects often show up as "organizational inertia causing missed transformation windows". So, setting up an institutionalized strategy for self-reflection-basically, regularly evaluating key indicators like developer retention and how the top apps are adapting-is a key way to proactively break out of path dependence and avoid repeating the PC-98 mistake. In the operating system industry, strategic flexibility is a survival skill. The earlier a team accepts that it may be wrong, the sooner it can cut losses on a failing path.

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