

Outgrowing production architecture: Case-based insights into diagnostics of strategic misfit

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Abstract: Many organisations operate production architectures designed long ago, with the goal of optimizing performance against yesterday's goals. Over time, these become increasingly misaligned with evolved demands for volume and complexity. This paper presents insights into recognition of when such architectures are outgrown, using a theory-building single-case study of an internal asset provider in discrete manufacturing, we analyse historical and present data, we identify four observable symptoms that co-evolve before significant performance deterioration. These are: Rising orders outside established architectural boundaries, complexity overflow inside the architecture, market-technical misalignment, and strategic misalignment. We propose pattern-based interpretation, emphasising broad co-movements over time. While bounded to large, data-rich, vertically integrated companies, the indicators are operationalized from available data, and can support earlier, evidence-based action.

Keywords: Product architecture, production architecture, architecture renewal, architecture governance, architectural drift

1 Introduction

Product architectures are generally made to sustain and should have lifetimes on a strategic scale (Harlou, 2006; Mortensen et al., 2016). Many organisations rely on product- and production architectures conceived long ago, optimized for a present which has long passed. In the meantime, markets shift, volumes rise or fall, product complexity and variety can expand, and customer requirements change. All of which are impactful towards architecture (Pasche and Magnusson, 2011; Piran et al., 2016; Salvador, 2007; Sanchez and Mahoney, 1996; Shamsuzzoha et al., 2020; Ulrich, 1995). This results in an incrementally built-up strategic misfit, where the gap between architecture capability and strategic goals slowly increases, and while performance can appear acceptable or even stellar when compared to yesterday's goals set in the development phase, the architecture may not be support reaching today's targets – not to mention tomorrow's. In the best cases, this means that the benefits promised by modularity disappear or degrade, and in the worst cases, this can mean an organization is forced to hastily restructure their operating model.

This paper studies the gradually emerging misfit that shows, when the demands profile of an enterprise drifts beyond the capability envelope embedded in their architecture (Salvador et al., 2002; Ulrich, 1995). We use the term “outgrowing” to denote a sustained mismatch between two areas. On the one hand, the evolved demand profile, and, on the other hand, the architecture capability that envelopes. This acknowledges that a company can outgrow its technology, in the same ways as a child naturally can outgrow their toys, consistent with the notion that architectures may require renewal as requirements change (Salvador et al., 2002; Shamsuzzoha et al., 2020). Outgrowing an architecture can take many shapes, e.g., spanning capacity, capabilities (Greve and Krause, 2018; Pasche and Magnusson, 2011) and value-chain constraints (Greve et al., 2022; Parslov and Mortensen, 2015).

The case company operates as an internal asset provider in discrete manufacturing of consumer goods, where production volumes have approximately doubled, end-product complexity has increased, and lead-times have been compressed. In response, the organisation has relied increasingly on local optimisations and workarounds rather than architectural renewal. Based on the described increase in orders executed outside architectural boundaries, growing architectural exemptions, rising platform proliferation, and widening market–technical gaps, this pattern may be interpreted as indicative of a structural challenge. Such developments are consistent with documented effects of increased interface pressure and coordination complexity under insufficient architectural governance (Bruun et al., 2014; Hölttä-Otto and De Weck, 2007; Løkkegaard et al., 2018; Ripperda and Krause, 2017). Taken together, these patterns suggest that the current architecture has outgrown its useful lifetime, becoming misaligned with strategic priorities and operational reality, motivating the evaluation of architectural redesign, rather than continued incremental fixes (Ripperda and Krause, 2017; Sanchez, 2013).

Although the field of product and production architecture is well covered, especially in the creation phases, from implications in development and operations (Piran et al., 2016), broad development decisions (Ulrich, 1995), and many methods for modular concept selection and portfolio-level design (Greve and Krause, 2018; Salvador et al., 2002), comparatively little scholarly attention has been given to architectural end-of-life or end-of-fit. Succinctly, diagnosing when it is better to abandon an existing architecture than adapt it. Existing literature covers in detail how to design and evolve and renew platforms (Parslov and Mortensen, 2015) and offers some insight into the timing of major transitions

(Bruun et al., 2014), yet systematic reviews highlight gaps in empirical, quantitative evidence and understanding of the conditions that cause organisations to (re-)modularize (Greve et al., 2022; Ripperda and Krause, 2017). As a result, theory-based managerial guidance on what warning signals to look for remains sparse, and methods more often support architecture-building and evaluation in narrower, more technical forms, rather than providing general end-of-fit diagnostics (Askhøj and Mortensen, 2020; Sanchez, 2013). This means that organisations risk deferring architectural renewal and accumulate local adaptations, increasing the risk of sub-optimization, and escalating coordination burdens, potentially necessitating more disruptive late-stage transitions to restore strategic and operational fit (Bruun et al., 2014; Campagnolo and Camuffo, 2010; Parslov and Mortensen, 2015; Sanchez and Mahoney, 1996).

The objective of this paper is to progress towards a simple, concise, and practice-driven diagnostics artifact for recognizing when organisations are outgrowing their production architectures. This is done through a theory-building, single-case study, using a mix of available quantitative and qualitative data to discover a set of measurable symptoms that appeared over time. These symptoms may be overlooked as they appear slowly, but artifact enables quantitative measures to notice the symptoms, and the diagnosis should be apparent long before significant performance deterioration. The study addresses the following research questions:

RQ1: What are the symptoms of an organisation outgrowing their product and production architecture?

RQ2: How can patterns of these symptoms be made interpretable and detectable for the decision-responsible managers?

The contribution that this paper makes is twofold; firstly, it describes the phenomenon of outgrowing an architecture, and secondly, it links the effects of this with observable, operational symptoms, resulting in an actionable list of four symptoms to look for, when evaluating the health of a production platform.

Methodologically, the analysis is done through access to operational data, and a broad set of stakeholder interviews within the case company. The observations put forth in the paper have all been triangulated, and validated against key stakeholders, to ensure internal validity. While the format of a single case study limits generalizability, the phenomena observed matches with the authors' previous experience within discrete manufacturing industries, and the authors believe that the indicators seen holds some degree of general applicability.

The remainder of the paper proceeds as follows: Section 2 outlines the research background and positions the study within literature. Section 3 covers the research design and case context. Section 4 describes the findings, and the goes into detail on the symptoms, while section 5 discusses the implication for theory and practice. Section 6 concludes the paper with contributions, limitations and future work.

2 Background

This section aims to give a brief introduction to the field of product architecture, with a focus on modular, platform-based architecture, relating the contents of this paper to relevant, well-recognized literature in the field, with specific focus on descriptions of architecture end-of-life within reviewed methodology.

While there are different definitions of the terms; *architecture* and *platforms*, this paper chooses to use the definition of an architecture from (Sanchez, 2013), viewing an architecture/architectures as strategic partitioning of a product into functional modules. In addition, the paper views platforms as embodiments of architecture, forming the basis for products, or assets, following (Askhøj and Mortensen, 2020; Harlou, 2006). Under this framework, different platforms can lie within a single architecture, which is in line with the notions of, for example, (Harlou, 2006). In extension to the theory on modular architecture- and platforms lies literature on applications within manufacturing, described by authors such as (Siiskonen et al., 2023; Sohrt et al., 2025).

Typically, methods within the field largely emphasize creation and restructuring of architectures. Methods such as the integrated PKT approach (Krause et al., 2014), the Product Family Master Plan (PFMP) (Harlou, 2006), or model-based system architecting (Menshenin et al., 2022) are mainly concerned with new product (architecture) development, or project-based architecture evaluations, evaluating platforms or architectures based on a snapshot in time. While some methods, like the brownfield method reflected by Lehtonen et al., 2011 are concerned with making the best use of existing development efforts, the authors have not found any explicit handling of emergent platform end-of-fit in the methods described above. Notably, end-of-fit for architectures is mainly handled implicitly, as planned architecture changes, and not something that may develop as enterprises and their technology mature in different directions. This motivates focus on emerging, operationally observable symptoms that may precede either a full mismatch or expected architectural renewal.

This paper is mainly concerned with firms outgrowing their product architecture. This phenomenon emerges, when an architecture that has previously performed well against the expected benefits, as described by for example (Baldwin and Clark, 2014; Krishnan and Ulrich, 2001; Salvador et al., 2002; Sanchez, 2013; Shamsuzzoha et al., 2020), can no longer deliver to these, meaning that accommodating new variants or changes triggers a rise in internal variety, unexpected change propagations and integration problems. In such cases, renewal or redesign of architecture is often needed, rather than only incremental updates, because external- and internal conditions have changed from the initial state beyond what the current architecture can absorb (Pasche and Magnusson, 2011). This can be driven by, for example, changing market demands (Greve and Krause, 2018; Pasche and Magnusson, 2011) or increasing pressure towards increased variation (Greve et al., 2022; Ripperda and Krause, 2017; Salvador et al., 2002).

3 Methodology and research design

This study focuses on theory-building research from a single-case study with a company selected based on significant and sustained growth over many consecutive years. The company has around 15 years of platform history, while roughly 5 years of asset history has been analysed.

The company serves as an internal asset provider in a major provider in the consumer goods industry. They provide specialized tooling for mass production of a highly diverse product portfolio consisting of around 3000+ products. They provide this tooling at a significant volume at 1000+ tools delivered each year.

The case is built on quantitative data from 5 years of operations data, order data (including which orders have been sent outside of architecture), and costing data. Also, qualitative data from more than 50 interviews across engineering, internal asset provider supply chain operations, corporate supply chain operations, and more have been gathered. All interviews have been conducted with full confidentiality for interviewees over the course of 1,5 years.

3.1 VALIDITY

This study is based on a single case of an internal asset provider within a global consumer goods company. As a vertically integrated internal asset supplier, architectural decisions, investment logic, and governance structures are shaped by corporate alignment mechanisms rather than external market competition. This organisational configuration may differ substantially from decentralised or market-facing supplier environments.

The consumer goods industry context constrains transferability. High production volumes, strong standardisation incentives, and long-lived platform interfaces amplify the relevance and impact of architectural governance compared to other industries.

Consistent with the case study methodology, the findings represent analytical rather than statistical generalisation. Broader empirical generalisation would require validation across additional industrial contexts and likely other organisational configurations.

4 Findings

In this section, the findings of the case study will be presented, leading with the introduction of the observed phenomenon of outgrowing architecture, followed by the four symptoms identified at the case company.

The conceptual model of the paper is built around an assumed causal chain: Shifts in volume, complexity, requirements (internal/external) and strategic priorities cause capability gaps in the platform, further causing the observable symptoms described in the chapters below, as the expected modularity benefits erode.

This section presents four recurring symptoms of architectural strain (RQ1) and examines how their interaction revealed a broader structural pattern under scaling conditions. The focus is descriptive, documenting how architectural misfit manifested in the case.

4.1 OUTGROWING ARCHITECTURES

In the case study, we observe an increasing divergence between the requirements of the enterprise, and the capabilities of its production architecture. This creates a performative ambiguity that must be addressed. It would be inappropriate to characterise the architecture as deficient, as it continues to perform in accordance with its original design intent. But it can also not be considered a good fit for the current context under which it has to perform. Rather, this is an indication that the platform in question is no longer the preferred fit for the current needs of the enterprise, necessitating a pattern of sustained compensating behaviours. In other words, we are seeing the symptom of what seems to be a renewed production paradigm, i.e. a different name of the game, or put simply, an enterprise outgrowing its historical, architectural decisions.

Specifically, we notice that this results in an increased amount of production orders being placed outside of standard architecture, along with a significant increase in complexity within architecture, and a decreased ability to live up to strategic goals. Through studying the case company, the authors have found four significant indicators, that an architecture may be at the end of its viable life, that appear before the performance is undermined to a level where attention from upper management will have to react.

During the empirical engagement with the company, four indicators of architectural misalignment has been identified, as detailed below:

1. *Orders outside of architectures*
An increasing share of asset orders are executed beyond established architectural boundaries, indicating that existing configurations cannot accommodate required technical performance nor functional specifications.
2. *Complexity overflow*
Rising numbers of architectural exemptions, engineering deviations, and platform variants suggest growing strain on the platform logic and increasing structural complexity. (see Figure 1).
3. *Market-technical misalignment*
The underlying technology base struggles to meet evolving market demands, creating performance gaps within the current architecture.
4. *Strategic misalignment*
Changes in sourcing constraints, regulatory requirements, or internal operational standards reduce alignment between the platform and corporate strategy.

These indicators suggest that the existing architecture may no longer adequately support evolving technical, market, or strategic requirements. Each indicator will be further detailed in the sections below.

4.2 ORDERS OUTSIDE OF ARCHITECTURE

This factor is perhaps the most undermining to the architecture, and in extension to the whole company. When orders are processed outside of architecture, two phenomena are observed; 1. Scale within the architecture is undermined, and 2. Additional processes may be needed to support the new processes and assets that now exist within the company because of circumventing the internal architecture. In short, the benefits of modularization and consistent architecture are not only crumbling but are actively being undermined by the decision of to order outside of the architecture.

Historically, according to the available data the overall split between the internal architecture and external sits around evenly distributed. This raises the question; if extraordinary exemptions are occurring regularly in a structured process – are they then exemptions? Or are they symptoms that the architecture no longer can deliver what is necessary?

Shown below in figure 1 we see the split between deliveries within the architecture, and outside of the architecture. Additionally, we have included an index of the number of platforms in the architecture. The initial impression is that the company includes more deliveries of assets within the core architecture by relying on a stabilized core architecture until ultimo 2021. The trend seems to plateau around here, where an expansion of the architecture is initiated. This would point toward a general lack of capability within the architecture, i.e., the inclusion into of assets into the core architecture is driven by an expansion of the capability of the platform itself. Succinctly, the inclusion is driven by an architectural scope creep. However, deliveries outside the architecture are also on the rise, indicating a general rise in demand. This could indicate that at least some of the scope creep happened as a reaction to a severe increase in demand. However, the trend stands that the rise in platform utilization is mediated by adding functionality to the architecture by introducing new platforms – from 2021-2025 the architecture counts an 80% increase of platforms.

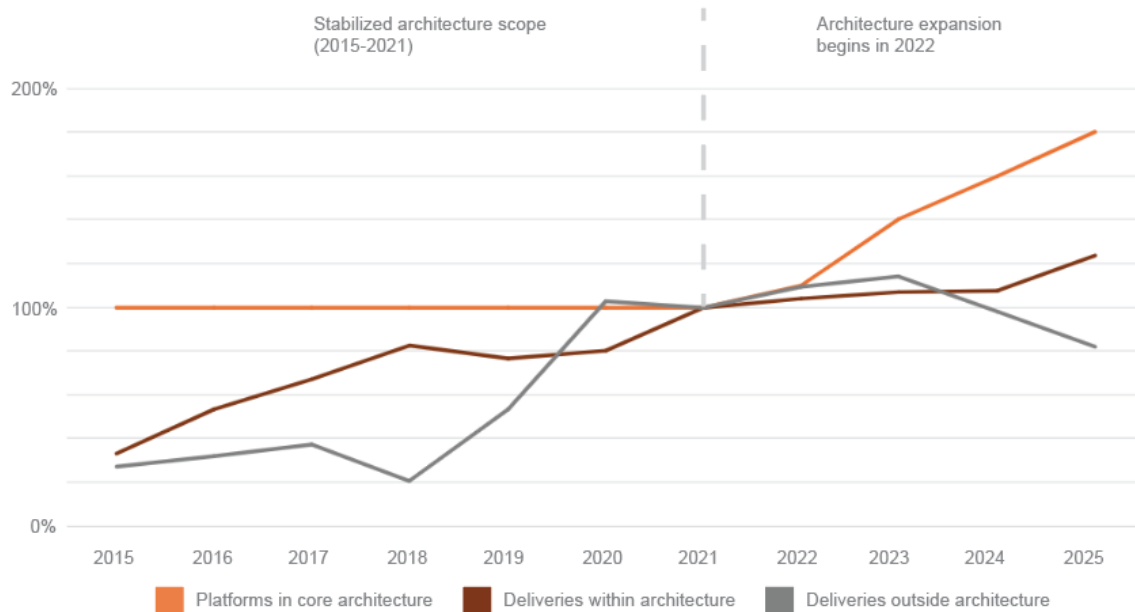


Figure 1 Indexed development (2021 = 100) of core architecture scope and share of deliveries classified within the core architecture. Inclusion improved under constant scope until 2021, with continued growth coinciding with expansion of the architectural boundary from 2022 onward.

4.3 COMPLEXITY OVERFLOW

The figure 1 also signifies a bigger issue. When platforms are added to the architecture, it also introduces complexity. Every new platform introduces new parts, new decision flows, new organisational and logistical requirements. With an increase of 80%, it is hardly unimaginable to suggest that the added complexity is directly proportional to this increase. This assumption is supported by interviews, as well as the fact that almost all platforms have between 12% and 24% unique parts associated with it.

The idea of introducing new platforms within the core architecture is initially a quick way to accommodate any oddly fitting orders. However, it comes at a risk of creating a Swiss army knife over time. Not specifically capable enough, not as broadly inclusive as intended. During times of demand expansions, it is increasingly difficult to align the existing architecture with added new generations (Askhøj and Mortensen, 2020).

Based on the figure 1, no clear boundary has been established for the architecture. This creates the possibility of introducing redundant new platforms, essentially re-covering existing platforms. With a platform where component commonality has been difficult to achieve, adding new platforms fundamentally only substantiates this issue. This makes it difficult to maintain long-term architectural consistency, while CAPEX increases slowly add up (Askhøj and Mortensen, 2020).

It was also found that although the company overall has included more designs into the core architecture, an increasing number of rejections are arising. This creates a bit of a technological oxymoron; the architectural proliferations were implemented to create better opportunity to utilize the core architecture, but the architecture itself still rejects an increasing number of designs. An indication that proliferation did not solve the initial architectural issue at hand. The addition in number of platforms in the architecture did, however, add an engineering pressure maybe due to an overly technologically encompassing architecture (Løkkegaard et al., 2018).

One overall finding is that the boundaries of the architecture has been challenged by alternating market demands, and that the added platforms diverged from the design rules of the architecture creating difficulty in a portfolio-wide governance structure. (Løkkegaard et al., 2018) argues that without explicit business-critical design rules, new architectures risk being introduced without alignment to existing portfolio and manufacturing capabilities, reducing the potential for reuse and increasing investment and time-to-market pressure. Ultimately, Løkkegaard et al., 2018. says, this can limit their ability to harvest modularisation benefits.

4.4 MARKET-TECHNICAL MISALIGNMENT

Since the architecture was operationalized, market demands have shifted significantly, introducing production tasks of a significantly different nature than what was present when the architecture originally was developed. The materials that the

tools interact with have changed due to different demands for mechanical properties as well as sustainability concerns, necessitating either changes in platform designs or significant compensations in other business areas.

Additionally, the architecture was designed to fit a certain range of production volume and complexity. Since then, both final product complexities have shifted, and production volumes have increased significantly. Key modules were designed for an upper bound in production volumes, which is no longer sufficient for today's demands, and redesign of these would require significant changes in the architecture. This is to say that the company has also outgrown their architecture in the most direct sense of the wording; by increasing production volumes to a point where its output is now too small, necessitating an amount of assets per production tasks beyond what is desirable.

4.5 STRATEGIC MISALIGNMENT

Originally, the architecture set out to reduce CAPEX expenditures by standardising an essential module shared throughout all the designs. To optimize return on investment, the company has chosen to scope the architecture broadly, including the most expensive assets used for high production volumes where potential CAPEX reductions were largest. The upfront benefits were yielded through direct CAPEX reductions, i.e. the architecture was successful in realizing the intended benefits. However, as the market evolved, it increasingly became a matter of reducing OPEX, since the actual lifespan of the assets, outlasted expectations significantly. Concurrently, demand increased severely making the OPEX of the assets magnitudes of the CAPEX. Thus, the foundation for optimization in the architecture, the very idea behind it is no longer grounded in the modern manufacturing reality.

In the pursuit of minimizing CAPEX and lead times, it has been chosen to increase sourcing flexibility, broadening the selection of suppliers from internal- and few carefully chosen external suppliers to a broader range. This effort has only been accelerated during the last years, where supply resilience has gained increasing focus inside the company. However, it has become apparent that the company designed their standardized parts in such a way that the design is optimized around the capabilities and working principles of their close supply partners, optimizing around these, and utilizing them the fullest. This has however shown to have the adverse effects of either difficult or unattractive to produce for new suppliers, putting additional strain on the internal value strain, decreasing buying strength in the relationships with external suppliers, and increasing supply chain risk. Overall, while this design lives up to the intended strategy at the time-of-design (by minimizing overall cost in the supply strategy at the time), strategy has shifted to a point where this has become a liability.

Another indicator of strategic misalignment is an increase in orders with delivery timelines shorter than the standard lead-time, indicating that the supply-architecture is no longer able to live up to production requirements. Increasing the severity of this symptom is the fact that the company has shown that external tooling suppliers are able to perform significantly better in this aspect, further indicating that this is a problematic attribute of the architecture at hand.

4.6 IDENTIFYING THE PATTERN

Although the four indicators described above may individually appear manageable, their concurrent existence reveals a broader structural pattern. The observations suggest not a discrete architectural failure, but cumulative strain associated with rapid organisational scaling.

Engineering capacity, manufacturing capacity, and architectural bandwidth were simultaneously stretched. As volumes, variation, and strategic requirements increased, the architecture was exposed to demands beyond its originally intended design space. The resulting deviations, i.e., the four symptoms, represent interrelated responses to this pressure rather than isolated anomalies.

Importantly, these dynamics were identified retrospectively. No early-warning indicators or formal, dedicated monitoring mechanisms were in place to signal architectural strain in the individual domains. Consequently, architectural drift occurred gradually, becoming visible only once multiple reinforcing symptoms had already materialised.

The pattern is therefore defined by the interaction of indicators. Taken together, they suggest an architecture operating beyond its effective design bandwidth under sustained scaling conditions.

5 Discussion

5.1 ANSWERING THE RQ

RQ1: What are the symptoms of an organisation outgrowing their product and production architecture?

The findings exemplifies that architectural outgrowth reveals itself in a combination of reinforcing symptoms across organisational levels, before it manifests as a single technical breakdown. We have identified four recurring indicators:

1. Increasing execution of orders outside established architectural boundaries.
2. Growing architectural complexity and platform proliferation.
3. Expanding market-technical performance gaps.
4. Strategic misalignment between platform constraints and evolving corporate requirements.

Individually, the symptoms are operational and observable, but not necessarily problematic in themselves. However, in combination they suggest cumulative architectural strain. The case indicates that organisations outgrow their production and product architecture not because the architecture seen in isolation is poorly designed but because the pressure of continuous scaling forces it to operate beyond originally intended capability envelope.

RQ1 contributes the identification of a symptom constellation rather than isolated failure modes.

RQ2: How can patterns of these symptoms be made interpretable and detectable for the decision-responsible managers?

The findings indicate that timely interpretability arises not from the presence of the symptoms individually, but from their frequency, interaction, and concurrent development over time.

In the case studied, no explicit early-warning indicators were in place systemically, and no suggestions towards this has been made. Resultingly, the symptoms developed gradually and we were only able to recognise them retrospectively. Architectural strain became detectable when:

- Deviations shifted from exceptions to recurring practice.
- Platform proliferation became measurable rather than anecdotal.
- Market gaps required repeated workarounds.
- Strategic constraints repeatedly forced architectural exemptions.

This suggests that detectability depends on reframing, what could seem like, isolated deviations as systemic signals. Decision-responsible managers may interpret increasing frequency and clustering of such deviations as pointers toward architectural bandwidth saturation rather than just operational noise.

The study does not propose a formal diagnostics artifact. Rather, RQ2 demonstrates how retrospective pattern recognition over four symptom domains can inform and facilitate more structured understanding of architectural strain and how to accommodate it before disaster strikes.

5.2 THEORETICAL IMPLICATIONS

Architecture and platform research has primarily focused on design, modularisation, and governance during creation and growth (Baldwin and Clark, 2014; Hölttä-Otto and De Weck, 2007). Far less attention has been given to how organisations effectively recognise the outgrowth of an architecture prior to observable performance failure.

This study extends end-of-life (EOL) perspectives by demonstrating that architectural decline manifests as structural strain cumulatively. Increasing boundary breaches, platform proliferation, market-technical gaps, and strategic exemptions signal saturation of the architecture's effective design space under scaling pressure.

The contribution is a clarification how architectural EOL presents itself gradually through drift and overload before collapse becomes inevitable.

5.3 PRACTICAL IMPLICATIONS

This study identifies four indicators that may signal, that a company has outgrown their architecture. These signals are induced by a case study and are operationally applicable. As such, the indicators presented in this paper is a significant contribution to a practitioner's toolbox, presenting an aid for determining the health of an enterprise's architecture. When the indicators occur with increasing frequency and in combination, they may indicate that the platform is approaching the limits of its effective design space. Monitoring such triggers can support earlier reflection on architectural renewal than compared to existing, reviewed methodologies, as these are visible before significant degradation of performance appears.

5.4 BOUNDARY CONDITIONS

The methodology has been developed in a large-scale manufacturer of discrete products with extensive experience within modularization, and a high degree of organizational maturity within the field, along with a high degree of vertical

integration, with focus on their internal production asset provider. The company has experienced substantial, sustained growth continuously, alongside the more general market changes over time. This combination of growth and technical expertise is unique, and it constrains generalizability. The diagnostic itself is most applicable, where long-lived architectures exist within defined boundaries. In less centralized, or market-facing suppliers, differences in logic, governance and competitive pressures may result in different symptoms, requiring adaptation of the framework for those organisational environments.

The approach also presumes a large degree of access to historical- and actual data, both quantitative and qualitative present in mature enterprises. In less mature environments, the prerequisite operationalization might prove challenging. Finally, the finite thresholds are highly contextual and not developed in this case study, but the persistent co-movement across all four was found to be a stronger decisional pointer than any absolute boundary. This can also prove difficult to gauge, as organizations change measurement- and KPI strategies dynamically. A standard for detectable data for the four indicators has not been developed, and thus specific data foundation used to measure these in this case might not apply generally. Resultingly, we claim analytical, rather than statistical generalization, and strongly encourage reproduction across industries and organizational configurations to refine the symptom definitions, their thresholds, and the necessary input data.

6 Conclusion

This paper has examined how an organisation may outgrow existing production architecture - not due to functional failure, but because evolving requirements exceed the capability envelope for which the architecture was originally designed.

Through this case study, four observable symptoms were identified that precede significant apparent performance degradation: orders outside of architectures, complexity overflow, market-technical misalignment, and strategic misalignment. Individually operational, these symptoms become structurally significant when their frequency increases and they occur in combination, indicating a potential end-of-fit condition.

The contribution of the paper is twofold. First, it conceptualises architectural outgrowth as a gradual process of cumulative strain rather than abrupt breakdown. Second, it clarifies how patterns of recurring deviations may become interpretable as early indicators of architectural misfit prior to significant performance degradation.

As the findings derive from a single case within a large-scale discrete manufacturing company with extensive modularisation experience, generalisability remains limited. Further empirical studies across alternative organisational and industrial contexts are required to assess broader applicability.

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