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Prototyping for Awareness of Potential Cascades

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Abstract

This article introduces a cascade-aware extension to systemic prototyping, building on a model that replaces divergence–convergence cycles with displacement and the accumulation of overlapping systemic maps. Within this framework, prototypes are redefined as instruments for introducing controlled displacements that reveal how effects propagate through complex systems.

Cascades are specified as processes in which the space of possible trajectories contracts as transformations align, reducing optionality faster than it can be restored. This emphasis on closure complements existing accounts of propagation by foregrounding the conditions under which alternatives are preserved or eliminated. Design is repositioned as a practice that engages with these dynamics, influencing how cascades form, travel, and stabilize.

The methodology integrates three coordinated modalities of prototyping: prospective, computational, and situated. Each modality introduces displacements at a different level of engagement with the system and produces systemic maps that capture propagation pathways under specific conditions. These maps are retained and overlaid, allowing multiple warranted readings of the system to remain active while supporting a graded notion of evidentiary strength.

The approach is demonstrated through extended examples in urban curbside allocation, municipal pilot programs, and hospital discharge processes. Across these domains, the method reveals patterns of amplification, attenuation, and redirection, supporting evaluation of interventions in relation to their downstream effects.

The contribution lies in articulating an apparatus for trajectory stewardship, enabling designers to engage with systems in terms of the cascades they invite, suppress, or redirect. By making propagation, closure, and recoverability visible, the framework supports more deliberate interaction with systems characterized by ongoing transformation.

Keywords: prototyping, cascades, systemic mapping, cascade detection, trajectory stewardship, design research

INTRODUCTION

A common image in design research presents the process as cycles of divergence and convergence: a controlled expansion followed by a disciplined narrowing, a breathing motion in which possibility is first opened and then resolved. The diagram developed by Juan de la Rosa offers a different geometry (de la Rosa & Ruecker, 2020; de la Rosa, Ruecker, & Giraldo Nohora, 2021). Instead of a funnel, it resembles a sequence of translucent layers, each one slightly misaligned with the last, like sheets of tracing paper that have been shifted, annotated, and placed back into partial register. What accumulates across these layers is not a narrowing of options but a thickening of the system itself as an object of study, aligning with broader moves in systemic design away from linear problem–solution models (Jones, 2014; Ryan, 2014).

Within this model, prototypes operate less like proposals and more like instruments. A prototype is a way of asking the system a question in material form. It introduces a disturbance, not to test whether a solution holds, but to observe what becomes newly visible when the system is compelled to respond. This view builds on participatory and cooperative design traditions in which prototyping is understood as an exploratory, situated activity rather than a reductive representation (Bødker, 1987; Bødker & Grønbæk, 1991; Floyd, 1984), and on later work that treats prototypes as epistemic devices capable of organizing inquiry and argument (Galey & Ruecker, 2010; Sanders & Stappers, 2014; Hillgren, Seravalli, & Emilson, 2011). Each displacement reorganizes attention. Elements that were peripheral may become central; relationships that appeared stable may reveal themselves as contingent.

As successive prototypes are introduced, the process produces a series of systemic maps. These maps do not replace one another. They remain active, each preserving the conditions under which it was generated. When overlaid, they form a composite representation that is richer than any individual view. This orientation resonates with accounts of infrastructural and socio-technical systems as relational, layered, and only partially visible in any single representation (Star & Ruhleder, 1996; Suchman, 2007). The resulting understanding does not depend on selecting the most accurate map. It depends on maintaining the coexistence of multiple warranted readings and using their intersections to articulate the system with greater precision of attention. Convergence, within this framework, is not a reduction of alternatives. It is a moment in which a proposed intervention aligns with the accumulated structure revealed across these overlapping mappings.

The extension developed in this article introduces an additional layer of attention: the dynamics of cascades. A cascade may be understood as a pattern of propagation in which a local change produces effects that travel through the system, sometimes amplifying, sometimes dissipating, sometimes reconfiguring the conditions under which further changes occur. Existing work on informational and network cascades has shown how local signals can align behavior and produce system-level effects (Bikhchandani, Hirshleifer, & Welch, 1992; Granovetter, 1978; Watts, 2002). In everyday terms, a cascade resembles a row of standing dominos, where a small initial push can generate a sequence of transformations whose extent and direction are not immediately obvious from the starting point. In more complex systems, however, the dominos are not arranged in a line. They are distributed across a network, connected through pathways that may only become visible once motion begins.

From the perspective of systemic prototyping, each displacement introduced by a prototype can be treated as a potential cascade initiation. The prototype does not simply reveal static relationships among elements. It activates pathways. It tests how change travels. It exposes where the system is tightly coupled and where it is loosely connected. This view aligns with systems research emphasizing leverage and nonlinear propagation (Meadows, 1999; Allen, 2014), while extending it into a design methodology grounded in iterative intervention. Some displacements produce limited local effects, like a pebble dropped into dense soil. Others generate wide-ranging transformations, more akin to a ripple moving across a surface of water. The difference between these outcomes is not incidental. It is a property of the system that can be studied, mapped, and, in some cases, modulated.

Incorporating cascade awareness into systemic prototyping therefore shifts the role of the map. A map is no longer only a record of elements and their relations at a given moment. It becomes a record of trajectories, capturing how changes introduced under specific conditions propagate through the system over time. When multiple such maps are overlaid, it becomes possible to identify recurring pathways of amplification, points of fragility where small disturbances produce disproportionate effects, and regions of stability where changes are absorbed without significant propagation. The composite map begins to function less like a static diagram and more like a field of tendencies, where different interventions can be understood in terms of the trajectories they are likely to set in motion.

This perspective introduces a new criterion for evaluating design interventions. Rather than asking whether a proposed solution addresses a predefined problem, the question becomes how the intervention participates in the ongoing dynamics of the system. An intervention may be judged in terms of the cascades it invites, the cascades it suppresses, and the cascades it redirects. A design that appears effective in a static representation may generate undesirable propagation when considered in terms of these dynamics. Conversely, an intervention that seems modest at the level of immediate outcomes may prove valuable by stabilizing or reconfiguring trajectories that would otherwise lead to undesirable system states.

The methodological implications of this shift are substantial. Prototypes can be deliberately constructed as cascade probes. Instead of aiming to approximate a final solution, a prototype may be designed to test a specific propagation pathway or to reveal the sensitivity of a particular dependency within the system. This extends existing accounts of prototyping as inquiry by making propagation itself the object of investigation (Koskinen & Frens, 2017; Kimbell & Bailey, 2017). For example, a prototype introduced into a service environment might be configured to slightly alter the flow of information between two actors, not to improve efficiency directly, but to observe how that alteration influences decision-making across the network. The resulting observations contribute to a growing archive of cascade-sensitive mappings, each one documenting how the system responds under particular conditions.

Over time, this archive supports a form of trajectory stewardship. The designer operates less as a selector of solutions and more as a custodian of system dynamics, attending to how interventions shape the range of possible futures available to the system. The accumulated maps function as a guide, indicating which regions of the system are prone to amplification, which are resilient, and where small adjustments may produce meaningful shifts in overall behavior. The work of design becomes analogous to tending a complex ecosystem, where the goal is not to impose a fixed form but to maintain conditions under which desirable patterns of growth and interaction can emerge.

This article presents the cascade-aware extension of systemic prototyping as an apparatus-oriented methodology. The aim is to provide a conceptual and practical instrument that can be used in research and practice. The apparatus is composed of three interrelated components: displacement through conversational prototyping, accumulation of overlapping systemic maps, and analysis of cascade dynamics across these maps. Each component is described in operational terms, with attention to how it can be implemented, documented, and interpreted within design research contexts.

By framing prototypes as probes of propagation rather than candidates for selection, and by treating convergence as alignment with accumulated system dynamics rather than reduction of alternatives, this approach offers a way to engage with complexity that preserves plurality while enhancing the capacity to act within it. The contribution lies not in proposing a new model of design as an abstract concept, but in articulating a usable method for studying and shaping the trajectories that define systemic change.

LITERATURE REVIEW

This article draws together four strands of scholarship that are usually discussed separately: systemic design, prototyping and participatory design, science and technology studies, and cascade research. The contribution of the article lies in assembling these strands into a methodological instrument for detecting how local design displacements propagate through systems and alter the availability of subsequent trajectories.

The first strand comes from design theory and systemic design. Simon (1969) framed design as the transformation of existing situations into preferred ones under bounded conditions, while Rittel and Webber (1973) established that many public and organizational problems are wicked in the sense that problem framing and intervention co-evolve. Later design research emphasized design's distinctive epistemic character (Cross, 2001; Buchanan, 2001) and expanded its remit from products to complex social and institutional systems (Irwin, Kossoff, & Tonkinwise, 2015; Jones, 2014; Ryan, 2014; Sevaldson, 2017). Within this trajectory, de la Rosa and colleagues developed a particularly relevant line of work in which systemic mapping, values-based inquiry, and participatory engagement are brought together through displaced prototypes and overlapping maps (de la Rosa, Kohler, & Ruecker, 2017; de la Rosa & Ruecker, 2020; de la Rosa, Ruecker, & Giraldo Nohora, 2021; Ruecker, de la Rosa, Oladeji, & Melton, 2020). The present article extends that line by treating each displacement not only as a map-generating move but also as a potential cascade initiation.

The second strand concerns prototypes as instruments of inquiry rather than reduced stand-ins for finished artifacts. Early work in cooperative and participatory design repositioned prototyping as a mutual activity through which users and designers explore possibilities together (Bødker, 1987; Bødker & Grønbæk, 1991; Floyd, 1984; Ehn & Kyng, 1987). Subsequent work widened this view by treating prototypes, probes, and scenarios as distinct but related forms of making in codesign (Sanders & Stappers, 2014), by examining prototypes as working artefacts in situated practice (Suchman, Trigg, & Blomberg, 2002), and by showing how prototypes can argue, inquire, and organize publics (Galey & Ruecker, 2010; Hillgren, Seravalli, & Emilson, 2011; Kimbell & Bailey, 2017; Koskinen & Frens, 2017). This literature supports the present paper's redefinition of prototypes as deliberate displacements introduced to reveal system behavior.

A third strand comes from science and technology studies and related work on infrastructure. Latour (1990, 1992) and Akrich (1992) showed how technical artifacts script action and stabilize social relations, while Star and Ruhleder (1996) and Star (1999) described infrastructure as relational, embedded, and often most visible at moments of strain or breakdown. Mol's account of multiplicity (2002) remains an important conceptual companion; within the present reference set, Suchman (2007), Verbeek (2011), and Winner (1980) are especially useful for understanding how heterogeneous actors, artifacts, and institutional routines co-produce action. These traditions support the article's insistence that overlapping maps can remain simultaneously active without requiring reduction to a single authoritative representation.

The fourth strand addresses cascades and propagation. Informational cascades explain how early signals can align later choices under uncertainty (Bikhchandani, Hirshleifer, & Welch, 1992). Threshold models show how local adoption can produce broader shifts once participation exceeds critical levels (Granovetter, 1978; Watts, 2002). Complexity and systems research adds a wider view of propagation, leverage, and nonlinear change (Allen, 2014; Meadows, 1999). What this literature does less often is provide a design-oriented method for making such dynamics visible through iterative, comparative interventions. The present article addresses that gap by combining systemic prototyping with cascade-sensitive mapping and by defining cascades not only through propagation, but through accelerated closure and changing recoverability.

Taken together, these literatures establish the components of the framework while also revealing the gap the article addresses. Systemic design contributes the move from isolated artifacts to interdependent fields. Participatory prototyping contributes an understanding of prototypes as epistemic and organizational instruments. STS and infrastructure studies contribute a vocabulary of mediation, scripting, and relational visibility. Cascade research contributes models of propagation, thresholds, and high-leverage change. The present article brings these together into a method for detecting how prototype-induced displacements travel through complex systems and how those travels reshape the space of possible futures.

CASCADES AS PROCESSES OF ACCELERATED CLOSURE

The examples that follow rely on a specific interpretation of cascades that differs in emphasis from the dominant treatments in the literature. Existing accounts in sociology, network science, and complex systems research have established cascades as processes of propagation, diffusion, and amplification. Informational cascades describe alignment of decisions under uncertainty (Bikhchandani, Hirshleifer, & Welch, 1992). Threshold models show how local adoption can trigger system-wide shifts (Granovetter, 1978; Watts, 2002). Work on complex networks traces how disturbances travel through interconnected structures, sometimes producing large-scale transformation (Barabási, 2016; Sornette, 2003). These traditions converge on the movement of effects through a system.

The present framework retains this emphasis on propagation while introducing a second dimension: closure. A cascade is defined here as a process in which the space of possible trajectories contracts as transformations align, reducing optionality faster than it can be restored. The defining feature is not simply that change travels, but that alternatives become unavailable through the interaction of constraints. Propagation and closure are co-produced. Effects move, and as they move, they reorganize the field of what can follow. This extension builds on systems-oriented accounts of leverage and nonlinear change (Meadows, 1999; Allen, 2014) while shifting attention to the availability of alternatives rather than to scale of effect alone.

This distinction becomes visible in situations where outcomes appear locally coherent while the system as a whole becomes less flexible. A navigation system that optimizes for travel time may produce efficient routes under stable conditions. As users converge on those routes, alternatives fall out of use. When conditions change, the system has fewer viable options available, and adaptation becomes more difficult. The cascade has not only propagated behavior. It has narrowed the space of possible responses. Similar dynamics have been observed in socio-technical systems where artifacts and infrastructures stabilize particular patterns of action while rendering others less accessible (Latour, 1992; Star & Ruhleder, 1996).

Closure operates through multiple mechanisms. In some cases, cascades select among existing trajectories, amplifying those that satisfy dominant constraints. In others, cascades reshape the terrain through which they move, altering the conditions that define what counts as a viable trajectory. A messaging interface that introduces a limited set of reaction options changes conversational dynamics by constraining how responses can be expressed. Over time, patterns of interaction align with the available forms, and alternatives recede. In more structural cases, cascades stabilize around existing patterns through selection processes embedded in institutional or computational systems. Predictive allocation systems that rely on historical data reinforce established distributions, reducing the capacity for variation to emerge outside the recognized frame. These processes echo analyses of how technical systems script and stabilize behavior (Akrich, 1992; Winner, 1980).

These configurations are not mutually exclusive. A single cascade may involve amplification, selection, and structural reconfiguration. The differentiation is analytic. It makes visible how closure is produced and where intervention might alter its progression.

The emphasis on closure introduces the concept of recoverability. A system retains recoverability when it can sustain multiple trajectories and shift among them as conditions change. Cascades reduce recoverability when they align transformations in ways that eliminate alternatives. The rate at which closure occurs relative to the system's capacity to generate or restore options becomes a critical parameter. When closure accelerates beyond that capacity, the system becomes locked into a narrowing range of futures. This concern resonates with design-oriented accounts of systems as evolving fields in which intervention shapes the conditions of future action (Nelson & Stolterman, 2003; Jones, 2014).

Design enters this field as a practice that engages with both propagation and closure. Reframing alters the initial conditions under which cascades form, redistributing attention and changing which trajectories are available (Schön & Rein, 1994; van der Bijl-Brouwer, 2019). Iterative adjustment introduces sequences of displacement that influence how cascades unfold, creating opportunities to observe and redirect propagation before alignment stabilizes. Constraint acquisition, a central activity in design, determines which trajectories are privileged and which are excluded, shaping the conditions under which closure occurs (Simon, 1969; Dorst & Cross, 2001).

From this perspective, interventions can be differentiated by their effects on cascade dynamics. Some act as amplifiers, increasing the rate at which alignment occurs and accelerating closure. Others function as dampeners, slowing propagation or redistributing effects across multiple pathways. Still others operate as redirectors, shifting the direction of propagation into regions of the system that can absorb or transform the effects without triggering undesirable closure. These roles are not intrinsic properties of the interventions themselves. They are relational, depending on the conditions of the system and the configurations into which the interventions are introduced.

The temporal dimension of cascades complicates their evaluation. Early stages are characterized by dispersed activity, where multiple trajectories remain available. Under these conditions, small displacements can significantly influence how alignment develops. As cascades progress, pathways consolidate, and the capacity to intervene from within the system diminishes. Late-stage interventions often require structures that are partially external to the cascade, such as alternative representations or parallel processes that preserve variation. The preparation of such structures becomes a design concern, introducing buffering as a strategy for maintaining recoverability. This aligns with work on infrastructuring and long-term system shaping in participatory design (Karasti, 2014; Hillgren, Seravalli, & Emilson, 2011).

Cascades frequently operate under conditions of apparent correctness. Outputs align with specified objectives, and local coherence is maintained. The contraction of alternatives may not be visible within the metrics used to evaluate performance. Over time, however, the loss of optionality reduces the system's capacity to respond to changing conditions. The cascade becomes evident not as failure but as diminished adaptability.

This framing establishes cascades as the analytic unit through which the subsequent examples are examined. The concern is not only how interventions produce immediate effects, but how those effects propagate and how they interact with constraints to shape the space of possible futures. By attending to closure and recoverability alongside propagation, the framework provides a basis for evaluating design activity in terms of the trajectories it sustains, suppresses, or redirects.

The sections that follow apply this perspective across three domains. Each example treats prototypes as instruments for introducing displacement and mapping the resulting cascade dynamics. The aim is to make visible how local changes travel through systems and how design can engage with the conditions under which closure accelerates or is delayed.

PROTOTYPING AS CASCADE INSTRUMENTATION

The term "prototype" carries strong prior associations within design discourse, often referring to partial realizations of a proposed solution that are evaluated for performance, usability, or feasibility. In the present framework, the term is re-specified to serve a different function. A prototype is defined as a deliberate displacement introduced into a system in order to observe how effects propagate under specified conditions. Prototyping, correspondingly, is the practice of constructing and deploying such displacements as instruments for revealing cascade dynamics. This re-specification builds on earlier work that positions prototypes as epistemic and organizational devices rather than merely representational artifacts (Bødker, 1987; Floyd, 1984; Sanders & Stappers, 2014; Galey & Ruecker, 2010).

This definition shifts emphasis away from representation and toward activation. A prototype does not stand in for a future state. It perturbs the present state. Its value lies in the trajectories it makes visible, including amplification pathways, points of attenuation, and conditional dependencies that shape how change travels through the system. This orientation aligns with research treating prototypes as situated interventions within socio-technical systems (Suchman, Trigg, & Blomberg, 2002; Hillgren, Seravalli, & Emilson, 2011) and extends it by making propagation itself the object of inquiry.

Three modalities are particularly relevant: prospective, computational, and situated prototyping. These are not alternatives but coordinated layers within a single methodological apparatus.

Prospective prototypes construct defined displacements within specified conditions and trace their likely propagation across a mapped system prior to implementation. This approach draws on traditions in futures and anticipatory design that use structured scenarios to explore system behavior under alternative conditions (Glenn, 2009; Zamenopoulos & Alexiou, 2007; Candy & Kornet, 2019). In the curbside case below, one might define a two-hour delivery window on a commercial block in New York and trace how delivery schedules, traffic flow, and pedestrian movement reorganize in response. In the hospital case, one might examine how simplified discharge instructions influence patient comprehension, medication adherence, and subsequent care-seeking behavior. The strength of prospective prototyping lies in its speed and scope. Multiple candidate displacements can be explored, and their potential cascade pathways articulated. The resulting maps remain conditional, providing structured expectations that guide further probing.

Computational prototypes encode displacements within a modeled representation of the system. These may take the form of agent-based simulations, workflow models, or structured replays of empirical traces. A curbside simulation might model vehicle arrival patterns and test how a delivery zone alters congestion under varying demand conditions. A healthcare workflow model might examine how changes in follow-up timing affect patient flow across care pathways. The advantage of computational prototyping is controllability. Parameters can be varied systematically, and specific propagation pathways can be isolated for analysis. This modality resonates with broader traditions of modeling and abstraction in design and systems research (Box, 1979; Allen, 2014). The limitation lies in representational scope. Cascades observed in simulation reflect the assumptions and boundaries of the model and may omit informal or emergent dynamics present in practice.

Situated prototypes introduce displacements directly into the system itself. These include temporary curb reallocations, pilot programs such as Shared Spaces in San Francisco, or modified discharge protocols within a hospital. Situated prototypes provide the highest ecological validity. They reveal cascades as they occur in practice, including unanticipated adaptations and interactions among actors. Their limitation is reduced control. Conditions cannot be fully isolated, and replication is constrained by context. This modality aligns with participatory and infrastructuring approaches in design, where interventions are embedded within ongoing systems and evolve over time (Karasti, 2014; Kimbell & Bailey, 2017).

The methodological contribution lies in coordinating these modalities rather than selecting among them. A prospective prototype may identify a plausible cascade pathway. A computational prototype can test the sensitivity of that pathway under controlled variation. A situated prototype can then probe whether the pathway manifests under real conditions. Each modality produces a systemic map tied to the displacement and the conditions under which it was generated. These maps are retained and overlaid, allowing multiple warranted readings of the system to remain active, consistent with approaches that treat design knowledge as emerging through layered and iterative inquiry (Koskinen & Frens, 2017; Scaletsky, Ruecker, & Basapur, 2014).

This layered approach introduces a graded notion of evidentiary strength. A cascade pathway observed across modalities carries greater warrant than one observed in a single form. At the same time, absence in one modality does not invalidate observations in another. It indicates that propagation is condition-dependent and requires further probing. The apparatus therefore supports both exploration and accountability, enabling designers to investigate potential trajectories while grounding their observations in progressively richer forms of evidence.

By redefining prototypes as cascade instruments, the framework extends systemic prototyping beyond its conventional role. Prototypes become tools for studying how local changes travel through complex systems, how they amplify or dissipate, and how they reshape the conditions under which future interventions occur. This re-specification aligns prototyping with the broader aim of trajectory stewardship, where design practice attends not only to immediate outcomes but to the dynamics that unfold over time.

EXTENDED EXAMPLE — CURBSIDE CASCADES, CONTROLLED PILOTS

Midday on a Manhattan block in New York: a delivery truck pauses at a hydrant while a second vehicle settles into a double-parked position just ahead; a cyclist threads the narrow gap that remains; diners occupy a wooden platform that has replaced two parking spaces; a pedestrian steps briefly into the travel lane to pass a stalled cluster near the curb. Each adjustment appears local and pragmatic. Taken together, they form a moving field of interdependent actions. The curb is not a boundary condition. It is an active interface where competing claims are continuously negotiated in real time.

Urban freight and curb management research has long described this condition in terms of scarcity and competing demand, with delivery vehicles, passenger pick-up, and pedestrian use all drawing on the same constrained resource. Studies in journals such as the Journal of the American Planning Association and Transportation Research Part E document how double parking, loading behavior, and informal rule-bending emerge as adaptive responses to this scarcity. During the COVID-19 pandemic, this adaptive layer thickened, as temporary street reallocations and shifts in delivery volume intensified interactions within limited space.

From a cascade-aware perspective, the scene can be read as a sequence of prototype-like displacements, even when no formal prototype has been declared. A temporary dining platform displaces two parking spaces. This change redirects delivery behavior, increasing the likelihood of double parking. Double parking alters traffic flow, which in turn changes pedestrian movement and cyclist routing. Each step produces conditions for the next. The cascade is not linear. It branches, overlaps, and sometimes loops back, as enforcement patterns and user expectations adjust.

To study this systematically, the method introduces deliberate displacements that function as probes. Consider a two-hour designated delivery zone introduced along one segment of the block. Conventional evaluation might measure compliance or efficiency. The cascade-aware approach instead traces propagation. Do delivery times compress into the designated window, producing new peaks? Does congestion migrate to adjacent blocks? Do pedestrians reclaim space previously occupied by idling vehicles, or does uncertainty increase their exposure to traffic? Each observation is recorded as part of a systemic map tied to the conditions under which it emerged.

A subsequent prototype might introduce a micro-hub for consolidated deliveries. Again, the interest lies in trajectories. The hub may reduce curbside dwell time for some vehicles while attracting new flows to its location. The resulting map captures not only immediate effects but the pathways through which those effects travel. Over multiple iterations, these maps accumulate. When overlaid, they reveal recurring patterns: zones of amplification where activity concentrates and propagates, and zones of absorption where changes dissipate without wider impact. The composite map begins to function as a field of tendencies, indicating how different interventions are likely to reorganize the system.

A complementary case in San Francisco provides a more deliberately instrumented setting. Programs such as Shared Spaces and formal curb management pilots treated reallocations as time-bounded experiments. Transportation and planning literature documents these pilots in terms of usage, compliance, and economic impact. Within the present framework, these same interventions can be re-read as structured probes of cascade dynamics. Because the pilots were documented, they offer clearer traces of how changes propagated. A temporary pedestrianization may show not only increased foot traffic within the zone, but shifts in vehicle circulation patterns, altered delivery schedules, and changes in adjacent business activity.

The urban cases establish how cascades can be observed in open systems with distributed agency. A hospital discharge system introduces a different configuration, where propagation occurs within tightly coupled institutional processes and where consequences are often measurable in clinical terms. Health services research has shown how small variations in discharge instructions, follow-up scheduling, or medication reconciliation can influence readmission rates, patient adherence, and caregiver burden.

Here, a prototype might take the form of a modified discharge protocol that introduces a structured follow-up call within 48 hours. Rather than evaluating success solely through reduced readmissions, the cascade-aware approach traces how this intervention reorganizes the system. Does earlier contact shift patient behavior in ways that reduce emergency visits? Does it redistribute workload among clinical staff? Does it alter communication patterns between hospital and primary care providers? Each effect is mapped in relation to the initiating displacement and the conditions under which it occurs.

A second prototype might adjust the timing or content of discharge information, perhaps simplifying instructions or altering their sequence. Again, the interest lies in propagation. Simplification may improve patient comprehension, which in turn affects medication adherence, which then influences recovery trajectories. At the same time, reduced detail may shift burden onto follow-up services, creating new dependencies. The resulting maps capture these intertwined pathways.

Across these domains, the same methodological structure is maintained. Prototypes are constructed as probes that introduce controlled displacements. Each displacement generates a map of observed effects, tied to specific conditions. Maps are retained rather than replaced, allowing multiple warranted readings of the system to remain active. When overlaid, they reveal patterns of amplification, fragility, and stability. Convergence emerges not as the selection of a single optimal configuration, but as the identification of interventions that sustain desirable trajectories while mitigating undesirable propagation.

The extended example demonstrates how cascade-aware systemic prototyping operates across different scales and institutional contexts. In the urban cases, cascades are visible in the shifting choreography of everyday activity. In the hospital case, they are traceable through clinical outcomes and organizational workflows. In both, the method provides a way to study how local changes travel, accumulate, and reshape the conditions under which future interventions occur. The contribution lies in making these trajectories legible and actionable, supporting a form of design practice oriented toward the stewardship of system dynamics over time.

EXTENDED EXAMPLE — HOSPITAL DISCHARGE AS CASCADE FIELD

A patient is discharged from a hospital bed in the late afternoon. The discharge summary is printed, medications are reconciled, instructions are explained, and a follow-up appointment is scheduled. Each of these actions appears bounded and procedural. Yet discharge marks not an endpoint but a transfer of responsibility across a network that includes the patient, caregivers, primary care providers, pharmacies, and, often, community services. The moment of discharge functions less like a conclusion and more like the release of a set of trajectories into a system whose stability depends on coordination across these actors. This perspective aligns with research in health services and socio-technical systems that treats care as distributed across interconnected practices rather than confined to a single clinical event (Suchman, 2007; Star & Ruhleder, 1996).

Health services research has repeatedly shown that small variations in discharge processes can produce disproportionate downstream effects. Studies in Health Affairs and Social Science & Medicine describe how gaps in communication, unclear instructions, or delays in follow-up can contribute to medication errors, missed appointments, and hospital readmissions. These findings are typically framed in terms of risk reduction or quality improvement. Within a cascade-aware framework, they can be reinterpreted as evidence of propagation pathways through which local changes travel and accumulate, consistent with broader models of cascade dynamics in social systems (Bikhchandani, Hirshleifer, & Welch, 1992; Watts, 2002).

To study these pathways, the method introduces prototypes as controlled displacements within the discharge process. Consider an initial prototype that restructures discharge instructions into a simplified, prioritized format delivered both verbally and in print. The displacement here is modest. The interest lies in how it propagates. Improved comprehension may increase medication adherence, which in turn stabilizes recovery. At the same time, simplification may shift interpretive burden onto follow-up interactions, altering the workload distribution among clinical staff. The resulting map records not only immediate comprehension outcomes but the pathways through which these outcomes influence subsequent events. This approach extends existing accounts of prototyping as inquiry by explicitly tracing propagation rather than only immediate effects (Koskinen & Frens, 2017).

A second prototype introduces a structured follow-up call within 48 hours of discharge. Rather than treating this as a discrete intervention, the cascade-aware approach traces how it reorganizes relationships across the system. Early contact may surface complications before they escalate, redirecting patients from emergency services to primary care. It may also alter patient confidence, influencing whether symptoms are monitored or ignored. The call itself becomes a node within a broader network of interactions, with effects that extend beyond its immediate content. This reflects the role of interventions as mediators within socio-technical systems rather than isolated actions (Latour, 1992; Akrich, 1992).

A third prototype adjusts the coordination between hospital discharge and community pharmacy services, ensuring that medications are available and clearly labeled at the point of transition. This displacement targets a known point of fragility. The cascade mapping traces how improved access affects adherence, how adherence influences symptom progression, and how these changes feed back into healthcare utilization patterns. At the same time, it records any unintended propagation, such as increased demand on pharmacy staff or shifts in communication patterns between providers.

Each prototype generates a systemic map tied to the conditions under which it was implemented. These maps include actors, actions, and observed effects, but also the pathways through which effects travel. Some pathways show amplification, where small changes lead to significant downstream differences. Others show attenuation, where changes are absorbed without wider impact. Points of fragility become visible where minor disruptions produce cascading failures, such as missed follow-ups leading to unmanaged symptoms and eventual readmission. Such patterns reflect the nonlinear and leverage-sensitive behavior of complex systems (Meadows, 1999; Allen, 2014).

When these maps are overlaid, a composite picture emerges. Certain pathways recur across prototypes, indicating stable channels of propagation. For example, the relationship between instruction clarity and medication adherence may appear consistently, while the link between follow-up timing and emergency department visits may vary depending on patient context. The overlay does not collapse these differences. It preserves them, allowing the system to be understood as a set of conditional tendencies rather than a single causal chain, consistent with approaches that treat design knowledge as layered and situational (Scaletsky, Ruecker, & Basapur, 2014).

Within this composite, opportunities for cascade modulation become visible. Some interventions function as dampeners, reducing the likelihood or intensity of undesirable propagation. A well-timed follow-up call may intercept a trajectory that would otherwise lead to readmission. Other interventions act as redirectors, channeling effects into more manageable pathways. Coordinated pharmacy handoff may shift patient behavior from reactive to planned care. These roles are not fixed properties of the interventions themselves. They depend on the conditions captured in the maps.

Convergence, in this setting, is not achieved by selecting a single optimal discharge protocol. It emerges through alignment with the accumulated understanding of how the system behaves under different displacements. A configuration is preferred not because it eliminates variation, but because it sustains trajectories associated with recovery while reducing the likelihood of destabilizing cascades. The resulting protocol remains open to further probing, as new conditions or patient populations may alter propagation patterns.

This example demonstrates how cascade-aware systemic prototyping operates within a tightly coupled institutional system. The hospital discharge process, often treated as a sequence of tasks, is reinterpreted as a field of potential cascades. Prototypes serve as instruments for revealing how changes travel through this field. The maps they produce support a form of design practice oriented toward the stewardship of patient trajectories, where the focus shifts from isolated interventions to the dynamics they set in motion.

RETURNING TO THE DIAGRAM — A CASCADE-AWARE EXTENSION

The diagram developed by Juan de la Rosa establishes a shift in how design activity is organized and understood (de la Rosa & Ruecker, 2020; de la Rosa, Ruecker, & Giraldo Nohora, 2021). Rather than staging work as expansion followed by reduction, it presents a process in which successive displacements generate overlapping systemic maps. These maps accumulate without replacing one another, allowing multiple warranted readings of the system to remain active. Convergence emerges through alignment with this layered understanding rather than through the elimination of alternatives.

The cascade-aware extension proposed in this article does not replace that structure. It introduces an additional dimension that operates across it. Each displacement already present in the diagram can be reinterpreted as a potential cascade initiation. Each resulting map can be read not only as a configuration of elements and relationships, but as a record of how effects propagate under the conditions introduced by that displacement.

This shift suggests a modification to the diagram that preserves its logic while extending its analytic capacity. The existing sequence of displacements and maps can be supplemented with a second layer that traces propagation pathways across iterations. Where the original diagram emphasizes accumulation through superposition, the extension introduces cross-cutting trajectories that connect elements across maps. These trajectories represent observed or anticipated cascades, indicating how changes introduced in one displacement travel through subsequent configurations.

Visually, this can be expressed by introducing connective structures that span the layered maps. Rather than arrows indicating linear progression, these connections form a network that cuts across iterations, linking points of amplification, attenuation, and redirection. The diagram begins to register not only the presence of multiple mappings, but the movement of effects through them. It shifts from a stack of views to a field of trajectories, aligning with broader understandings of systems as relational and dynamic rather than static (Star, 1999; Sevaldson, 2017).

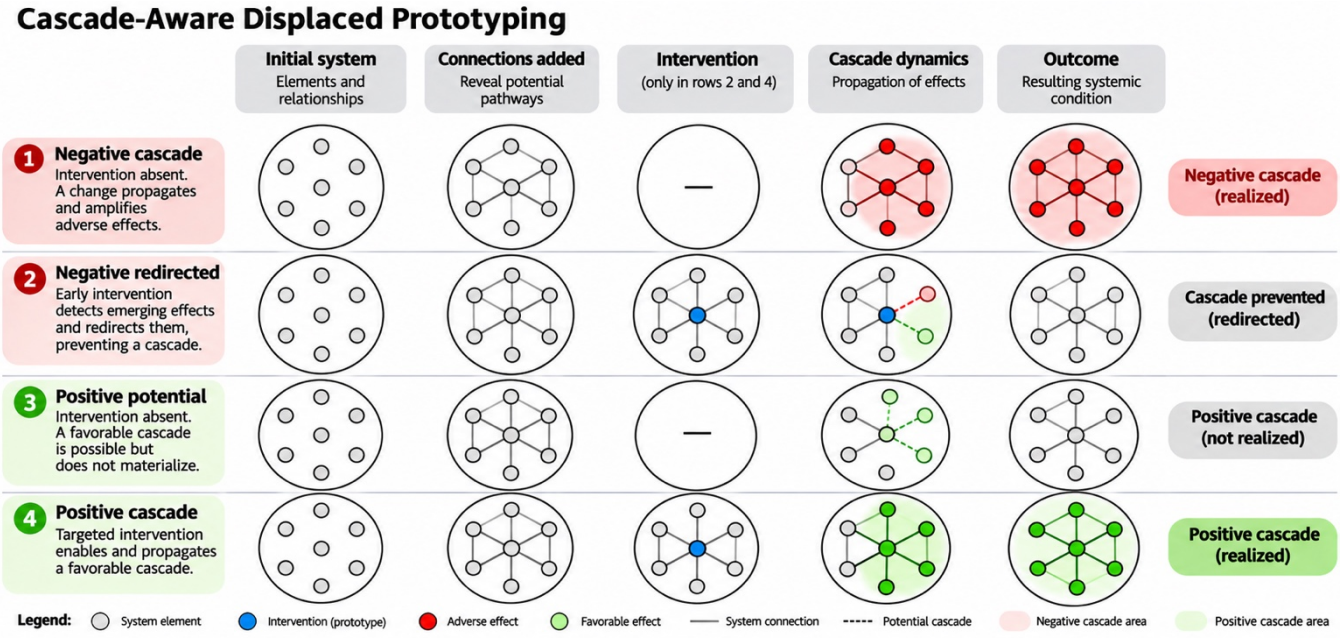


Figure 1. Cascade-aware extension of displaced prototyping, building on de la Rosa and Ruecker (2020) and de la Rosa, Ruecker, and Giraldo Nohora (2021). Prototype interventions can reveal, redirect, or enable cascades across interconnected systems.

A second adjustment introduces markers of closure and recoverability. Points at which trajectories narrow can be indicated as zones of accelerated alignment, where multiple pathways converge and alternatives diminish. Conversely, regions in which variation is sustained can be marked as zones of recoverability, where multiple trajectories remain available. These markers are grounded in the behavior of cascades rather than imposed from outside the system.

A third addition incorporates buffering structures. These are elements that are not fully aligned with the dominant trajectories and that retain the capacity to introduce alternative pathways. In the diagram, they can be represented as partially external or loosely coupled components that connect to multiple layers without being fully absorbed into any single configuration. Their presence reflects the importance of maintaining alternative structures that support adaptation within evolving systems (Karasti, 2014; Hillgren, Seravalli, & Emilson, 2011).

Taken together, these adjustments reposition the diagram as a representation of both structure and movement. The original emphasis on displacement and accumulation is retained. The extension makes visible how those displacements participate in cascade dynamics, how propagation unfolds across iterations, and where intervention may influence the rate and direction of closure.

The modified diagram does not prescribe a sequence of steps. It functions as an instrument for reading and constructing systemic situations. Designers can use it to identify where displacements are likely to initiate cascades, to trace how those cascades travel across the system, and to locate opportunities for dampening, redirection, or buffering. The diagram becomes a working surface for trajectory stewardship, supporting decisions that account for both immediate effects and downstream propagation.

CONCLUSION

This article has introduced a cascade-aware extension to systemic prototyping, positioning design as a practice that engages with propagation and closure within complex systems. By defining cascades as processes of accelerated closure, the framework directs attention to the conditions under which alternatives are preserved or lost. This shift complements existing accounts of propagation by specifying how alignment among transformations reduces optionality over time.

Prototypes have been redefined as instruments for introducing displacement and observing how effects travel under specified conditions. The coordination of prospective, computational, and situated prototyping provides a layered apparatus through which cascade dynamics can be explored and grounded. Each modality contributes a different form of warrant, and their integration supports both exploratory and accountable engagement with system behavior.

The extended examples demonstrate how this apparatus operates across domains. In urban curbside systems, cascades are visible in the redistribution of activity across contested space. In controlled municipal pilots, they can be traced through documented interventions and their effects. In hospital discharge processes, cascades unfold through tightly coupled clinical and organizational pathways. Across these contexts, the method provides a means of mapping how local changes propagate and how they interact with constraints to shape future trajectories.

Returning to de la Rosa's diagram clarifies the relationship between the original model and its extension. The accumulation of overlapping maps remains central. The addition of cascade tracing introduces a second layer that makes movement through the system legible. The resulting representation supports a form of design practice oriented toward trajectory stewardship, where interventions are evaluated in terms of the cascades they invite, suppress, or redirect.

The contribution of this work lies in articulating a usable methodological instrument. It does not replace existing approaches to systemic design. It augments them by providing a way to engage with dynamics that are often present but not explicitly represented. By making propagation, closure, and recoverability visible, the framework supports more deliberate interaction with systems that remain in motion. A subsequent paper develops complementary strategies for engaging these dynamics directly, examining how interventions can modulate propagation, closure, and recoverability across systems.

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