Possibility theory: A foundation for theoretical and empirical explorations of uncertainty

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1. INTRODUCTION

The field of operations and supply chain management (OSCM) has a long history of identifying and engaging with risk and uncertainty in operational practices.[1] We provide a brief review of uncertainty in the OSCM domain, alongside an overview of our Special Issue (SI) call and accepted manuscripts. This serves as a starting point for the introduction of a new theoretical framework that reframes uncertainty as unresolved states of *possibility*. In this framework, the term *possibility* can refer to a broad array of OSCM actions and solutions including the novel application of existing approaches or technology as well as completely novel practices that enhance organizational outcomes. We illustrate the path-dependent evolution in these possibilities, alongside the limitations and opportunities imposed on the set of available possibilities resulting from concurrent evolution in the broader socio-technical system. We present the benefits of deploying a broader array of methodologies in the empirical study of what is, and is not, possible at discrete points in time, as well as the dual process of constraint and expansion in possibilities over time. The resulting empirical efforts to understand possibilities, in turn, enable novel theory development, elaboration of existing OSCM theory, and opportunities for bridging to other disciplines.

1.1 Traditional perspective on uncertainty

When uncertainty is foreseeable or predictable it can be modelled, under various states of nature, as a set of choices and their outcomes. This lends itself to the application of statistical

[1] Risk manifests when operational outcomes are stochastic, but the underlying generating process is known or can be assumed to be known in the short term. Uncertainty manifests when the generating process of the operational outcome is unknown.

approaches and analytical modeling tools (e.g. maximax, minimax regret, Hurwitz criterion and expected opportunity loss). Considerable research effort has explored the events and conditions that may impact these probabilistic models and underlying probabilities, as well as developing extensions to optimize the response to uncertainty in operational outcomes (e.g. utilization, yield, throughput) and efficacious ways to respond to external influences like customer demand and preferences (e.g., Boute et al., 2022; Charpin, et al., 2021; Gao & Chen, 2015; Leung & Sun, 2021).

A parallel stream of research explores the extent to which uncertainty is knowable. One example of such uncertainty arises from managerial ignorance – events that are knowable in principle, but not taken into consideration – with the resulting epistemic uncertainty labelled *knowable unknowns* (Packard & Clark, 2020; Ramasesh & Browning, 2014). In the face of this form of uncertainty, firms benefit from revisiting their decisions around complexity and complicatedness, and the heuristics they draw upon when responding to, or mitigating, operational consequences of unanticipated events (e.g. Feduzi et al., 2022; Ramasesh & Browning, 2014). Another type of uncertainty is unforeseeable, or aleatory, uncertainty (so-called *unknown unknowns*). Here, the probabilistic approaches and assumptions that predominate OSCM research fall short as this form of uncertainty is the result of '…some inherent, a priori causal indeterminism that cannot be mitigated…" (Packard & Clark, 2020, p.770). In practice, tools like insurance and forward contracts can provide straightforward and fruitful pathways for managerial action in the presence of unknown unknowns (Holmes & Westgren, 2020). At the same time, mitigation of known or knowable forms of uncertainty may not be viable due to the cost/benefit ratio or bounded rationality. Nevertheless, distinguishing epistemic uncertainty from aleatory uncertainty guides the use of predictive and non-predictive strategies. This distinction may also be helpful in rationalizing perceptions of uncertainty that can emerge at the intersection of high complexity processes and the cognitive limitations of managers and workers; where one can effectively consider the unfortunate emergence of 'unknown (or incomprehensible) knowns' (Bendoly et al. 2006, Sterman et al. 2015).

1.2 The special issue

In developing the proposal for the SI, we envisioned that the operational disruptions and uncertainty caused by recent events (such as the pandemic, regional conflicts, and natural disasters), presented a unique opportunity for advancing the theoretical frameworks and practical relevance of the OSCM field (Disney et al., 2021). We sought contributions providing novel theoretical and empirical insights for coping with uncertainty and environmental turbulence, as well as case and interventionist research to revisit and augment existing theory and generate novel insights for practice. We also solicited manuscripts that embraced uncertainty as a pathway to generate new goals and purposes, and studies introducing the role of creativity, experimentation, and innovation in relation to uncertainty; these aspects of our call received little response.

The majority of the 64 manuscripts submitted to the special issue align with OSCM's established theoretical and empirical lenses on uncertainty: events, responses to events, and mitigation of undesired outcomes. These submissions adopted a combination of qualitative and probabilistic approaches to managing uncertainty within the limits of managerial decision-making. The final editorial process yielded five accepted papers.

Two manuscripts followed our call for work on OSCM planning and managerial decision-making under uncertainty. Thirumalai et al. (2024) undertake a conventional statistical exploration of how variability in demand affects performance. In examining the impact of patient mix and volume variability in 731 hospitals in the Midwest U.S., they find both mix and volume uncertainty impact the number of procedures performed and patients' length of stay. Lu et al. (2024) examine managerial decision-making, leveraging scenario-based experiments to assess managerial sensemaking during supply chain disruptions. The authors find that disruption breadth and depth influence managerial perceptions of the anticipated impact of the disruption. As the scope of countries and suppliers involved increases, so does the managerial propensity to explore ideas of supply chain resilience.

A common theme across most of the submissions we received was the OSCM repercussions of difficult-to-forecast, high-impact events. One of our accepted manuscripts provides an excellent example of how existing OSCM practice choices influence possibilities for novel reconfiguration and repurposing of operational systems in response to environmental demands. Dube et al. (2024) illustrate the path-dependent nature of system-level strategic agility. Their longitudinal case study shows how the UK government's OSCM strategies developed to manage medicine shortages in anticipation of Brexit subsequently enabled a pivot to address the needs of the COVID-19 pandemic.

High impact events also provide opportunities to develop new insight on the use and efficacy of existing OSCM approaches. Here, Durach et al. (2024) illustrate how the location of inventory buffers across the supply chain influenced financial performance in the wake of a major earthquake. Ignatius et al. (2024) investigate the impact of a typhoon on the deliveries of home appliances. Based on detailed monitoring of individual deliveries before, during, and after the storm, the authors make inferences on how supply-chain complexity affects performance.

We thank the reviewers and Associate Editors who supported the special issue. We are deeply grateful for their time and insight. As we reflected on the editorial process, we were also struck by the often-insurmountable expectations the OM community placed on manuscripts following a normative theory testing pathway. Of the almost 150 reviewer and Associate Editor reports that we handled, all but a handful recommended rejection. We applaud rigor but also recognize the various challenges that accompany empirical work in real world contexts. These contexts are inherently complex and empirical work will come with limitations and shortcomings. We encourage our colleagues undertaking the critically important and often thankless work of reviewing, to seek the value and unique insights manuscripts may offer[2]. In broadening our theoretical and empirical lenses to incorporate a possibilities framework, and the temporal dependence and evolution in the OSCM practices and solutions that are possible over time, there is an opportunity for a more encompassing perspective on uncertainty. Realization of this potential requires openness to a broader set of methodologies and an interest in outliers and unique exemplars. It also requires that we, as the OSCM community, embrace a broader array of methodological tools and celebrate efforts at nascent theory building and theory elaboration.

2. A POSSIBILITIES LENS

Much of the OSCM literature views uncertainty through the lens of risk (real and probabilistic, or perceived). Other areas of management examine uncertainty from the perspective of available solutions and possible alternatives, as well as *opportunity by design* (e.g. in entrepreneurial ventures, strategic decision-making, and policy); see Alvarez and Barney (2007), Dimov (2016), and McBride and Wuebker (2022). This latter framing shifts uncertainty away from a troublesome factor to be mitigated and towards a source of potential value creation and progress. We conceptualize economic activity and operations as part of a larger, nearly decomposable, evolving structure (Simon, 1962, 2002). This offers the opportunity to redirect OSCM uncertainty research towards a deeper reflection on what actions and solutions are *possible* or *impossible* in an evolving socio-technical system – a system in which OSCM is deeply embedded (Arthur, 2009; Simon, 2002). Artificial systems evolve not just through competition and selection but also through purposeful cultivation and design (Simon, 1996).

[2] This is emphasized, for example, in mandates for developmental reviews at journals like the *Journal of Operations Management* (see guidelines at www.jom-hub.com).

Thus, with technology in the socio-economic context of a complex system, OSCM is part of this larger autopoietic[3] system – continuously regenerating itself, from itself (Holland, 1995). This centres our attention on the temporal aspect of our work. Specifically, it requires a consideration of how the world is, how it can and cannot be in the future, alongside how it could have been in the past (von Wright, 1951; Hintikka & Hintikka, 1989).

As noted earlier, possibilities can entail a wide range of OSCM actions and solutions. They include novel technologies, practices, and procedures, as well as re-imagined applications of existing ways of doing things. Possibilities can involve the deployment of technologies (e.g. AI, drones, virtual reality), changes in management policies and practices (e.g. TQM), operational process infrastructure (e.g. digital supply chains), strategies that present a novel way of working (platforms, sharing economy), and the application of algorithms (forecasting mechanisms, replenishment policies, Vendor-Managed Inventory - VMI). If the construct appears broad, that is because it is. The opportunity rests not just in identifying solutions, but in the way in which the possibility sets expand or are restricted over time.

Perspectives such as the theory of constraints (Goldratt & Cox, 1984) provide the logic-driven thinking processes and problem-solving tools that can also support the discovery and charting of a wider set of possible operations scenarios (e.g. Groop et al., 2017; Öhman et al., 2021). However, it is challenging to formulate scenarios for a dynamically evolving socio-technical system. Even though we have a general understanding of the nature of technological evolution (Arthur, 2009), we lack methods for describing and investigating it. Industry 4.0 illustrates the methodological challenge in an OSCM setting. Despite the significant research efforts to understand the unfolding opportunity of technology in manufacturing industries, the literature lacks detailed studies of how possible operations and opportunity changes over time.

[3] An autopoietic system is a system that produces and reproduces its own elements as well as its own structures (Luhmann, 2012, p. 32).

While researchers do not have full visibility of the domain, we will suggest that one of the challenges is our preference for inferential statistics and theory testing. The backward-looking focus of these tools means they are not ideal for developing our empirical and theoretical understanding of emerging areas of practice.

Table 1 provides a simplified overview of how the research landscape changes with a shift in focus from (a) mitigation and response to knowable and unknowable events in an open system and towards (b) an understanding of the factors that constrain and enlarge our possibilities set for operations practices. This new perspective includes developing frameworks to understand how the possibilities set that firms can select from comes into being (evolves) and may be actively enriched or augmented in a more bounded (and knowable) socio-technical system. Incorporating the repertoire of possible and infeasible possibilities into our research endeavours, alongside the evolutionary constraints and opportunities on that repertoire imposed by the socio technical system, provides important opportunities for developing novel theoretical lenses on understanding uncertainty. It also presents a valuable pathway to enrich the methodological approaches we draw upon.

Table 1 - Perspectives on Uncertainty

	Uncertainty Lens	**Possibilities Lens**
Approach/aims	Risk mitigation, and response to knowable and unknowable events	Understanding factors that constrain or enlarge our possibility set – opportunity for value creation and progress
Temporal view	Past/present	Past/present/future
Theoretical goals	Theory testing Theory elaboration	Theory elaboration Nascent theory building Inform literature beyond OSCM
Methodological premise	Historical data distributions and relationships are indicative of anticipated future relationships	Past practice defines realized / unrealized possibilities, which constrain and enable current and future possibilities Evolving socio-technical system
Methodological approaches	Inferential statistical approaches Observational, case studies, experimental	Outlier exploration, Configurational analysis, edge contexts, interventions, scenario modeling, design thinking
Etiology	Correlational	Generative logic, production of effects and constraints
Analytic approaches	Robust optimization, ambiguous probability distributions	Small world representations, limiting conjectures, counter theories
Learning about key constructs	Linear and additive effects, generalized causal relationships	Synergistic and equifinal effects Problem discovery
Opportunity in OSCM	Reduce sources of uncertainty Hedge risk Mitigate impact of uncertainty	Explore diversity of feasible actions and lost opportunity Understand emerging dependencies Direct attention to missing factors required for valued possibilities to be realized Engage with complex system interdependencies Address technological and environmental transformation where prior data is not helpful or available Revisit fundamental assumptions underlying core constructs

We propose a conceptual framework of possibilities, drawing inspiration, in part, from an evolutionary model of language change developed by Lock (2018). In examining possibilities, we incorporate associated modalities (impossibility, possibility, certainty). This conceptualization enables the study of possible but unrealized operations (lost opportunity, counterfactuals); feasible, but constrained operations (entrepreneurial and strategic opportunity); and possible future operations and supply chains (technological foresight). Possibilities in this model are distinguished temporally:

1. ***Actualized possibilities*** reflect those possibilities that have been realized in the past, from the set of possibilities that were available at the time (what has been). By contrast, *unrealized possibilities* are possibilities that could have been acted upon but were discarded or ignored.
2. ***Available possibilities*** are the rich array of possibilities available at the current point in time (what can be). For any given actor, the menu of *available possibilities* emerges from the evolution in the socio-technical system in which it is embedded. It is constrained or enabled, in part, by past actualized or unrealized possibilities.
3. ***Feasible possibilities*** are those that may become available in the future (what may be). This is a prospective lens and is conditional on the currently available possibilities that are actualized, those that remain unrealized, as well as new possibilities that emerge through technological, societal, and other changes.[4]

[4] Note that on each time horizon, path dependence (selection) *reduces* the number of possible solutions, and re-combination (design) as well as environmental evolution *increases* the number of possible solutions.

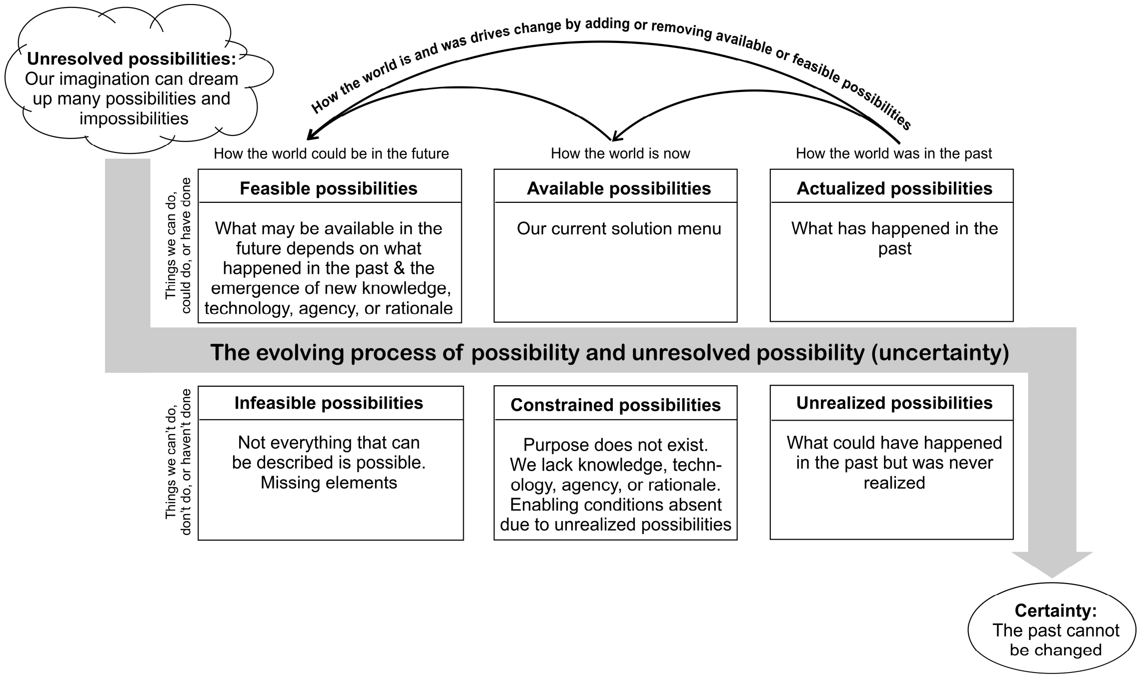

Figure 1: Possibilities as an evolutionary process

Our proposal for how to approach uncertainty from the vantage point of possibilities is pictured in Figure 1. Within this framework of possibilities and unrealized possibilities, uncertainty manifests as unresolved states between actualized/unrealized and available/constrained possibilities. Viewed from left to right, the framework is akin to the technology funnel, with many more feasible possibilities than are ever actualized. Uncertainty pertains to what are feasible new combinations, as well as the emergence or removal of possibilities. This is a type of uncertainty of practical and theoretical interest: How do firms identify and enact desirable possibilities and avoid undesirable ones?

Flowing from right to left, the emergence of new technologies and practices expand the possibilities set. Further, time itself expands the possibility set available to organizations. For example, more possibilities for managing unanticipated demand emerge as one's time horizon lengthens into the future (e.g. via inventory buffers or stockpiles that require some time to establish). Equally, time may lead to the emergence of new and unforeseen possibilities, and it may lead to the emergence of enabling elements that allow possibilities to be actualized. For example, VMI was conceptualized as a means to provide suppliers with production and delivery flexibility by giving them responsibility for replenishment, decades before the practice was adopted by companies in the 1980s (Magee, 1958; Disney & Towill, 2003). The technological shifts that made it truly viable took time to materialize.

There are also restrictions that emerge going from right to left, resulting from path dependence. For example, VMI was superseded by forecast-based replenishment solutions. However, this step back from VMI means suppliers lose flexibility on supply delivery and real-time visibility on customer demand, leading to restrictions on the possibilities available to them. Both actualized and unrealized possibility can drive evolutionary change by adding to, and removing from, available possibilities and feasible possibilities. Our framework thus describes possibility as an evolutionary process and uncertainty as an unresolved possibility.

At any point in time, there are always many more feasible and available possibilities than are actually realized. Uncertainty manifests around the nature of possibilities (e.g. future feasible/infeasible, currently available/constrained, and prior actualized/unrealized). Uncertainty occurs when we cannot determine the next state of the possibility sequence from prior knowledge. The cause of uncertainty differs by type of possibility. For example, it could be the delayed impact of unrealized prior possibilities, or incomplete knowledge of the broad array of factors that might render a future possibility infeasible. Investigating and resolving the differences requires deploying appropriate methods and research designs. Our theoretical framework can also distinguish between the possible and the impossible. Note that the figure does not include what is certain. For example, the laws of physics dictate with certainty that the past cannot be changed, and that many things that can be said are impossible.[5] Of course, managers and workers may operate with opposing perceptions of what is and is not possible, due to natural cognitive limitations, but that is a separate (albeit critical) discussion for OSCM researchers and practitioners.

Consider further our previous example of managing unanticipated demand and the possible solution of inventory buffers. Without upstream suppliers committing resources for manufacturing at an earlier point in time there is no buffer inventory to drawdown in an emergency, thus removing that inventory as a possible solution (Durach et al., 2024). Realized possibilities may likewise generate new possibilities. For example, Dube et al. (2024) show how operational practices and systems developed for one context may allow organizations the possibility to repurpose those systems in response to an unanticipated environmental context. Similarly, as external technological shifts occur, previously infeasible possibilities may become viable at a later date, expanding the realm of possible solutions. For example, although interest in VMI has waned, improvements in monitoring and diagnostics have allowed a vendor-managed solution for condition-based replacement of spare parts to become a possibility (Akkermans et al., 2024).

3. RESEARCH ON POSSIBILITIES IN OSCM

We explore research on possibilities in operations and supply chain management through the examination of two critical questions: How do we conduct *empirical* research on possibilities? How do we foster *theoretical contributions* based on empirical studies of possibilities? The

[5] There are simple and direct relationships that are certain and fully determined by physical laws, such as planetary movement (Newton 1687). There are also very complex physical relationships that are certain, even though not fully modeled and measurable, such as the atmospheric greenhouse effect (Arrhenius 1896). Furthermore, there is also the impossible, where physical laws and non-existence leave no room for uncertainty even though we can imagine it. For example, we can imagine the benefits of time travel, but not realize it. Thus, from the perspective of possibility, uncertainty is the special case of not certain, not impossible (Wittgenstein et al, 1969).

current emphasis on confirmation and theory testing centers much of the empirical work in OSCM on actualized possibilities. Indeed, the statistical models at the core of these research endeavors assume ergodic stochastic processes where past expectations and probabilities predict future ones (Davidson, 1991). Not all possibilities are actualized, and future possibilities are subject to ongoing systemic change in the technological, institutional, and social environment. Expanding our methodological toolkit to examine the process of evolving possibility offers rich opportunities for both empirical exploration and theoretical innovation. In the next section, we illustrate how less common approaches to empirical research in OSCM can serve to enrich our understanding of feasible-available-actualized/infeasible-constrained-unrealized solutions. We follow this with a discussion of how empirical efforts can inform nascent theory building and theory elaboration, and provide important connections to, and influence on, other disciplines.

3.1 The empirical study of actualized/unrealized and available/constrained possibilities

Our field's preference for inferential statistics has led to tremendous progress in understanding actualized possibilities. Indeed, relationships identified via inferential statistics are at the core of OSCM theoretical propositions and the associated testing and validation efforts. These efforts presume that core relationships will stay stable over time, and by extension, that actualized and unrealized possibilities also mirror available and constrained operations. Our possibilities framework suggests that the evolution in the external environment may void this assumption of stability and indicates the benefit of revisiting and testing core OSCM relationships. Our focus on inferential statistics also leaves important opportunities in the methodological landscape for conducting empirical research on possibilities. We provide three examples below: 1) pursuing *outliers*, 2) seeking out *unique, uncommon contexts*, and 3) unpacking the role of *configurations*.

3.1.1 Outliers

Inferential statistical models often manifest significant levels of unexplained variance. *Examining outliers* in these models present opportunities to understand the diversity of possibilities that have been actualized. As one concrete example in this special issue, Lu et al. (2024) statistically examine hospital department patient mix and volume variability in relation to the number of procedures performed and patient length of stay. While they draw conclusions largely in line with expectations, their data includes instances of departments that deviate significantly from these normative patterns. For example, while mix uncertainty increases the number of procedures in most department types (controlling for a host of factors), it decreases them in cardiology and endocrinology departments. Case-based work examining these instances presents an opportunity to understand the broader set of actualized possibilities in the management of hospital departments. Sterman and Dogan (2015) provide an empirical example of how exploring outliers from prior studies can extend our theoretical understanding of uncertainty. They re-examine outlier cases from Croson et al. (2014) as a basis for novel theorizing and testing the possibility of endogenous hoarding and phantom ordering in supply chains.

Outliers need not always reside in the larger data sets that serve as foundations for much of the empirical OSCM research; they can also emerge from possibilities that reside outside of the OSCM domain. For example, for several decades, object-interactions have provided the interfaces between human users and their computing devices, allowing simpler and more intuitive device use. In contrast, products in manufacturing and logistics continue to predominantly interact with machines and equipment via procedural and transactional controls. Stark et al. (2023) illustrate a case firm that allows material items to interactively control direct digital manufacturing equipment for their laser cutting and machining, and handling robots for their movements. Handling robots update the location of items with each movement, resulting in a manufacturing system where no item is unaccounted for or misplaced. Stark et al. (2023) show how this interactive product-computer interface in production control allows simplified planning, processing, and handling in manufacturing. Digitally encapsulating the control of manufacturing and handling of components (Holmström et al. 2019) thus empowers completely new OSCM possibilities.

3.1.2 Unique and uncommon contexts

Expanding our empirical explorations to unique and uncommon contexts – where environmental, societal, and interorganizational stressors are different from those traditionally examined in our research endeavors – provides an important means to explore the varied enabling conditions and possibilities that can manifest. OSCM would benefit from examining such contexts, including exemplars of important societal differences (e.g. inflation, demand variability), industry differences (e.g. variation in interorganizational stressors such as design changes and product obsolescence, misplaced inventory), and technological capabilities (e.g. contexts with different levels of digital connectivity or different income levels which enable or prevent the deployment of technologies). Exploring more diverse contexts can thus inform practice in environments where such stressors are less frequent or enabling conditions are absent. In the process we gain fresh perspective on the evolution of actualized possibilities and the emergence of previously unrealized possibilities.

Research contexts in OSCM are traditionally fairly stable. When that stability is disrupted, we gain additional insight on the boundary conditions of well understood available possibilities, as well as less understood unrealized and constrained possibilities. For example, in this special issue, Dube et al. (2024) show how the UK government's preparations for medicine shortages due to Brexit subsequently facilitated its pivot in response to the COVID disruption. In the same vein, Bendoly et al. (2024) illustrated how existing additive manufacturing capability served as a starting point for firms to pivot to new products and meet surging demand for critical supplies. Differences in firm commitments to generative design (a new AI-enabled technology for product design) defined variation across firms and the observed set of available and constrained possibilities. Environmental disruptions influence the landscape of what is and will be possible, and Bendoly et al. (2024)'s study highlights the salience of a configurational approach to understanding this process of expansion and constraint.

3.1.3 Configurations

Configurational explorations are often lacking in empirical OSCM work, yet a number of studies have shown that configurations play an important role in understanding what is possible. For example, early work on lean manufacturing highlighted the important interactions between buffers, work organization, and HR practices as a key differentiator between mass and lean production (MacDuffie, 1995). Having one element of the configuration – key HR practices like contingent compensation and high levels of training among others, provided factories the possibility to take on other elements of lean production like on-line work teams and devolution of quality improvement efforts to production workers at a later point in time (Pil & MacDuffie, 1996). Indeed, configurations are key to delineating the presence (or absence) of necessary or sufficient conditions that enable or restrict the available possibilities. Here, the field's preference for inferential statistics limits the scope of empirical work, in part because of constraints on the interactions that can be modeled and the sizeable number of cases needed to test a large number of potential interactions. Set-theoretic tools, like fsQCA, provide an important pathway to address these shortcomings. They also provide an important mechanism to incorporate insight from qualitative work (Ragin, 2008), and form the foundation for analyzing configurations of practices, including rare and unusual sets that represent realized possibilities. For example, Jiang et al. (2024) apply configurational analysis to examine supply chain resilience in Chinese manufacturing firms. Their study identifies how proactive and reactive supply chain resilience depends on different configurations of information, operational, and relational integration, alongside varied dimensions of big data analytics capabilities. Understanding different enabling conditions provides more nuanced insight on the possibilities that are realized or unrealized by organizations.

3.2 The empirical study of feasible/infeasible possibilities

The previous section discussed approaches to understanding available and actualized possibilities. However, the landscape of possibilities is constantly evolving in response to technological, social, and environmental changes, some of which may be external to the focal OSCM relationships under investigation. Grounded theory, through interviewing, observing, conceptualizing, and iteratively testing our understanding and insight, provides some perspective on evolving possibility, both sociologically and organizationally. However, we also risk missing systemic changes and emerging opportunities if they are not on the radar screen of those we engage with. In this section, we examine two aspects of feasible possibilities that can be explored empirically, based on the configurational nature of possibilities: 1) The role of missing elements that constrain the viability of future possibilities; and 2) the emergence of new elements that make new possibilities feasible.

3.2.1 Missing elements that constrain feasible/infeasible possibilities

Counter theories (Ehrig & Schmidt, 2022) provide an important approach to examining the required elements (and current constraints) for a feasible possibility. Using this method, researchers develop conjectures about what may be a future feasible possibility, and the basic premises that must be true for that conjecture to be realized. They can then examine those premises that are currently empirically testable to make inferences about untestable assumptions, and to develop an understanding of the likelihood that the conjecture is a feasible possibility. Researchers leverage the combinatorial characteristics of available solutions to test the weakest assumptions that pertain to the possibilities that are explored. When such assumed conditions are rejected, it opens the door for a critical examination of the possibilities that are built on those conditions (Chalmers, 2002). This can in turn provide important inputs for the design of solutions, interventions (actualization) and registered field experiments to undertake examinations that control for potential confounds and confirm counter-intuitive findings (Chandrasekaran et al., 2024). While this form of inquiry may not yet have much traction in OSCM research, it follows a long tradition of deploying *Kaizen* in OSCM practice. Managers ask the "five whys" – even when they believe they already understand the best pathway forward (de Treville et al., 2023). Applied to feasible possibilities, researchers can likewise identify a set of conditions that are necessary to attain what they identify as a worthwhile possibility to pursue. And like in Kaizen, as each of those conditions are evaluated and reflected upon, they may be judged to be false or contradictory with other conditions. Where this approach differs from Kaizen is that not all conditions need to be evaluated - only those conditions that are most unclear and uncertain.

As was the case with available possibilities, the consideration of diverse contexts allows the exploration of the specific conditions where possibilities can be fostered and developed that may not naturally appear on the radar screen for researchers. For example, George and colleagues (2022) offer an example of an empirical study on a technologically feasible supply chain design. In seeking to address discrimination and unfair labor practices through product tracking and disintermediation, the study also identifies the enabling factors that are needed for the full realization of emancipatory technologies as an available possibility.

3.2.2 Expanding elements that make new possibilities feasible

Empirical approaches to studying available possibility focus on solution components that are *present,* but perhaps constrained. Expanding our scope, we can explore the equally interesting question of what is *absent,* and what can be made *redundant*. For example, the manufacturing control solution noted above in Stark et al. (2023), manages material items in a way that makes inventory management and accounting redundant. However, without robotics the solution would be infeasible. To make the solution feasible with manual handling and conventional warehousing a different configuration would be needed. The solution element that is currently missing is the feasibility of an interactive control configuration for the manual handling of materials. This interactive control might be achieved, for example, via training video-based large language models to track the movement of items and interactively updating their location. While such a novel machine vision component is currently not used for this purpose, it is feasible and in development (e.g. via Nvidia's Omniverse platform). Recognizing the technological feasibility of a novel way of managing material items, allows us to consider specific implications in terms of novel practices, concepts, and theory deriving from the possibility that inventory management (as we understand it today) becomes redundant in the future.

3.3 Using possibilities for theory

Over 30 years ago, Gigerenzer (1991) revealed how methodological tools shape theory, and as shifts in normative methodology take place, the theories shaped by those methodologies take primacy.[6] This same phenomenon has manifested itself in the OSCM field, where a heavy reliance on analytical and multivariate statistical approaches has played a dominant role in the field's approach to theory. As we have discussed above, reframing uncertainty as possibility necessitates an expansion of the methodological approaches to OSCM inquiry. This presents an opportunity to generate new pathways for theorizing and widens the scope of questions that can be addressed. Actualized, available, and feasible possibilities serve as a starting point for

[6] Gigerenzer (1991) showed how the evolution in statistical methods of inference was directly mirrored in the design of theories of cognition.

methodological expansion and the introduction of technological and socio-technical methods in nascent theory building and elaboration. We highlight two ways in which studies of possibility can contribute to our theoretical frameworks: 1) nascent theory building and elaboration, and 2) theoretical bridging to other disciplines, e.g. strategic management, organization, and public policy.

For nascent theory building and theory elaboration in OSCM, framing and conceptualizing the empirical problem in its context is critical (Bendoly and Oliva, 2024). In a similar vein, proactive efforts to identify feasible possibilities and edge contexts where possible operations are taking shape is important to enriching and elaborating the repertoire of OSCM theories. Several decades ago, Klahr and Simon (1989) highlighted the contribution of outliers to the process of inquiry. We have already identified several approaches to identifying such exemplars – whether by looking at outliers in statistical analyses, or unique environmental conditions and circumstances that have spawned less common realized possibilities. These surprises provide opportunities to revisit what is deemed possible. They can serve as the basis for abductive reasoning (Behfar & Okhuysen, 2018) allowing researchers to move from data to theory building. For example, intervention-based research designs provide a pathway to move directly from the identification and highlighting of mismatches between expectations (established theory) and reality (outliers), to nascent theory development (Chandrasekaran et al., 2020; Oliva, 2019).

The effort to enable nascent theory development and theory elaboration can be broadened by establishing a tradition of reporting unique exemplars, unusual cases, and unexpected findings. In medicine, this takes the form of 2000 word case reports. In the OSCM field, we would similarly benefit from unique cases of both success and failure – either in brief form to illustrate a unique solution to a problem, or as rich examinations of how an organization engaged with a complex situation and the solutions it developed and deployed. The latter are nothing new but have become less common in recent years. Layered and compelling narratives have played crucial roles in understanding OSCM in key industries (e.g. the captivating accounts from the auto industry on Toyota, Saturn, Ford, and GM played an important role in what became our theoretical frameworks for explicating lean manufacturing and high involvement work systems). These cases provide a rich presentation of the mangle of practice and a deep look at the role of time and agency (Pickering, 1993). The complex array of unexpected twists and turns offered new ways of theorizing around the possibilities that were, are, and can be.

As we deepen our understanding of what is possible, we can revisit well-established constructs (e.g. inventory, order management, productivity, quality, product supply, etc.). Revisiting core constructs that have been taken for granted, opens new opportunities for conceptualizing problems and opportunities, and provides novel pathways for theorizing. For example, if inventory is reconceptualized as locating physical product items using their digital counterparts, theoretical frameworks based on transactions and physical flows become less useful and may need to be supplanted by new frameworks and theories.

Future possibilities present perhaps the greatest challenge for empirically based theory building. However, recognizing that this may entail examining counter theories, as well as deep examination of current possibilities – available/constrained as well as actualized/unrealized – provides a pathway for an empirical investigation of future possibilities. To assess the conditions underlying such counter theories of feasible future possibilities, researchers can for example, engage teams of experts to assess the most constraining elements required for the possibilities to be realized. Combined with empirical data, this expert-based exploration can be further contextualized and grounded. For example, to assess future possibilities for assuring availability of critical supplies in a pandemic, researchers might integrate empirical data associated with specific scenarios (e.g. export bans, labor unrest, port congestion) that impact feasible possibilities (manufacturers pivoting to new products), alongside available possibilities (e.g., mandating reshoring or near-shoring production) and actualized possibilities (e.g., sourcing supplies from low-cost regions). This can then set the stage for a team of knowledgeable experts to evaluate the specified possibilities, and propose alternatives, incorporating understanding of the broader eco-system and socio-technical influences (yet even then, there remains a risk of missing unanticipated systemic change and inertia).

When Japanese manufacturers in the 1980 and 1990's captured the interest of practitioners and academics with their novel ways of operating, OSCM provided concrete examples and concepts for new theory development that led to thriving new streams of literature in different knowledge domains. For example, Teece et al. (1997) built on insights from Lean Manufacturing in their development of dynamic capabilities in strategic management. Benner and Tushman (2003) drew on quality and process management in introducing ambidexterity to organization science. Adner and Levinthal (2001) relied on the product-process framework from operations management in their work on technology evolution that set the stage for the vibrant innovation ecosystem literature. Broadening the methodological approaches that OSCM draws upon to understand, empirically and theoretically, how new possibilities build up from actualized to available, to future possibilities provides important opportunities for novel theory development – whether it be addressing societal challenges like pandemics/global warming or outlining the potential impact of critical new technologies like AI. Possibilities research, including identifying the broad range of possible operations and the enabling conditions for those to become a reality, can provide new opportunities to not just spark nascent theorizing in OSCM, but also contribute to the theoretical growth in related fields like strategy, entrepreneurship, and organizational theory.

4. CONCLUDING REMARKS

Establishing how uncertainty relates to possibility and unrealized opportunity, reveals new ways to conduct impactful research in operations management. Our possibilities framework empowers the OSCM community to recognize available operations that are not actualized and in turn prompts empirical investigations of the constraints that play a role for those possible operations. Likewise, identifying feasible operations that are not available, directs our attention to missing elements, such as developing technological solutions, introducing missing actors into the socio-technological system, or redesigning/reconfiguring current operations with future needs in mind. We can examine the value that is lost for different actors and for society when operations that are possible are not actualized, and in turn, inform relevant strategy and policy. Possibility thinking can likewise provide policy insight by shedding light on how we can enrich the set of possibilities to address important societal needs. This positions OSCM to contribute more effectively in efforts to solve grand challenges like geopolitical conflict, climate change, dwindling resources, and aging populations.

The possibility lens, and its focus on the temporal dynamics of what is and is not possible, requires that we broaden the methodological approaches we draw upon. We hope that in turn, the possibility perspective also spawns new theoretical ideas and frameworks for the OSCM field and other knowledge domains, alongside important insight for practice and policy.

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