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Impact pathways: towards an adapted understanding of the development of operational capabilities

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Abstract

Purpose – This study is intended to motivate and guide future researchers to rethink and update their theories of operational capability development. By examining the extensive body of research on operational capabilities and working closely with an industry partner, the authors are iteratively developing new thinking about why our existing models seem to be failing and what aspects are likely to be useful in updating them.

Design/methodology/approach – This pathway paper is based on observations gained through a structured literature review, close collaboration with an industry partner and discussions with other industry partners and executives.

Findings – The authors identify ways in which the operations management community could begin to challenge and expand existing models of operational capability development. They provide reflections on the network structure of operational capabilities, i.e. their interconnectedness and interactions, which are likely to evolve dynamically over time and have not yet been part of the authors' thinking about operational capability development.

Originality/value – The authors hope to stimulate new research through this pathway paper. By synthesizing their existing knowledge of operational capabilities and collaborating with an industry partner, the authors have attempted to highlight their limited knowledge of capability development. In addition, the authors offer several opportunities to rethink their existing models.

Keywords Operations strategy, Competitive priorities, Operational capabilities

Paper type General review

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Through the authors' exchange with executives, they noticed that world-class businesses seem able to perform well across all main competitive capabilities. Compared to competitors, they offer shorter lead times, better quality, higher variety, better sustainability performance and generally more value for money. The literature has suggested ways to achieve this and the authors were therefore surprised to learn that many of these companies appear to dismiss both tradeoffs and a sequence of capability building suggested by leading scholars. Digging deeper, the authors learned that they seemed to dynamically and continually rotate their focus among the operational capabilities depending on the situation they were facing. This was an intriguing observation to which the extant literature on operational capabilities did not provide an explanation.

For more than three decades, operations management (OM) scholars have attempted to describe the development of operational capabilities in organizations. However, the focus has mostly been on tradeoffs or sequential development and no models include rotating foci. So, are the old models wrong, or in need of revision? In this *Impact Pathway* article, we identify new and highly relevant challenges and questions for the OM community regarding capability development. Answering these questions is fundamental to the discipline because operational capability development is at the core of OM.

In this paper, the authors present their emerging understanding of how the OM community should start challenging and extending the existing models. The authors elucidate on how operational capabilities are *interconnected*, how they *interact* and suggest that they likely dynamically *evolve* in a company's given environment.

The state-of-the-art

Companies are competing on the development of operational capabilities like cost efficiency, quality, delivery, flexibility and, more recently, sustainability. The question is not whether capabilities matter but how to build and sustain them most efficiently. Our field (see Appendix 3) has been trying to find an answer to this question since the mid-1990s and a review of the literature reveals three key shifts in thinking – with this pathway, we want to point out the need for the next shift.

Skinner (1969) introduced the *Tradeoff Model* in the 1960s. It suggested that improvements in one capability can only be achieved at the expense of others. For example, the tradeoff idea suggests that quality comes at a price, meaning companies cannot be very cost-efficient and simultaneously deliver very high quality.

In the 1990s, the *Cumulative Capabilities Model* was suggested as a fundamentally different approach to tradeoffs (Ferdows and De Meyer, 1990). One primary reason for its emergence was that cutting-edge companies of that time—in particular Toyota Motor Corporation—offered high-quality products at low costs and faster than any of its competitors, which contradicted the central thesis of the Tradeoff Model. The new Cumulative Capability Model entails that the four classic capabilities—quality, dependability, speed and cost—do not have to be traded off against each other but can be built up sequentially in precisely this order (see Appendix 2). A key point in the cumulative model is that investments in higher-level capabilities require continuous further investment in lower-level, more fundamental capabilities—of which quality is most fundamental. Building capabilities cumulatively is like pouring sand, layer by layer, into a sandcone: the lower capabilities grow broader as the higher capabilities are built.

After substantial empirical testing of these two prevalent models, scholars have dismissed the universality of both. Tradeoffs do not seem to exist in a meta-analysis of the literature (Rosenzweig and Easton, 2010), studies find other sequences than the originally suggested one in the Cumulative Capability Model (Flynn and Flynn, 2004) and new theory seeking to integrate both is based on firms' resource orchestration, which is hard to measure. There is little doubt that these theories are valuable and offer helpful perspectives, but overall they have not been subject to robust confirmation (Schmenner and Swink, 1998; Vastag, 2000). Scholars have instead

derived various hybrid models (Hallgren *et al.*, 2011; Rosenzweig and Easton, 2010). We seek to re-direct the scholarly attention towards working on a universal model in this *Pathway*.

Methodological approach

This pathway paper was motivated by our finding that companies regularly have difficulties developing their capabilities according to the tradeoff model or the capability development model. These insights stem partly from discussions with industry partners and executives in MBA or other programs and partly from teaching these models ourselves. This led us to engage in a deeper exploration of operational capability development knowledge (see Figure 1).

We started with a systematic review of the literature searching premier OM journals (see Appendix 1). After our literature review, we contacted one of our key industry partners, Lufthansa, to discuss and better understand modern capability development. One of the company's senior executive managers began collaborating with us on this project and has co-authored this paper. In 2020 and 2021, we conducted a series of repeated in-depth interviews and discussions with the head of continuous improvement and the accountable manager.

Our engagement with this company and the literature allowed for the iterative development of new thoughts regarding capabilities. This abductive approach of creating new knowledge by circulating between evidence and theory is common in our discipline but is often hidden behind more accepted terms such as deduction or induction. However, the linkages and observations we share in this study are less deterministic than what deduction or induction would produce.

We explain our resulting conclusions and suggestions regarding capability development in a current business context with all its complexity. We do not claim that the preliminary conclusions we derive from this process are universally true, or even that they are the only conclusions that can be derived; what we offer is a first, intuitive theoretical leap of thought that calls for further work and examination. Hence, a *pathway* for the future.

Introducing the idea of Hub-and-Spoke capabilities

Our goal is to share our collective insights from working with industry partners, particularly Lufthansa and suggesting a pathway forward for rethinking existing models. We were particularly interested in looking at Lufthansa because the recent pandemic has forced Lufthansa and its subsidiaries to rethink their business model and potentially enter new markets. As a result, Lufthansa is in the midst of a process of questioning and re-evaluating its operational capabilities and taking a hard look at its competitors.

In our discussions, we quickly noticed that the better-performing companies are not sticking to static competitive priorities. Instead, they appear to dynamically rotate their focus among capabilities, allowing them to account for resource limitations, move at a fast pace and respond to competitive pressure. We present our thoughts and observations and explain how

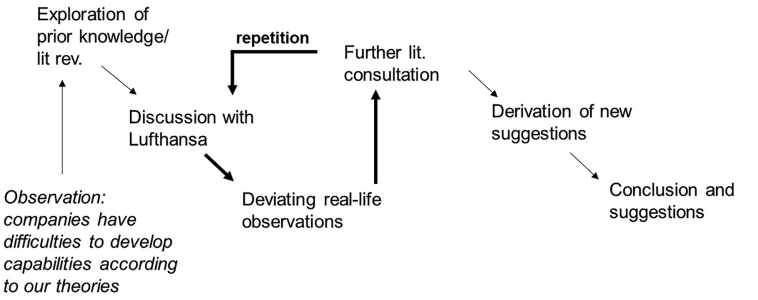


Figure 1.
Path of research based on the abductive research process

they may expand and change our view of the legacy models. We try to summarize these thoughts in what we call the Hub-and-Spoke Capability View.

We conclude that it is unlikely that a one-size-fits-all model can explain the development of operational capabilities in modern organizations. Therefore, one of the premises of the Hub-and-Spoke Capability View is that it provides a company-specific dynamic perspective on operational capabilities. Companies typically first try to identify the specific capabilities that have positive and strong links to other capabilities and then invest in them. Each company seems to have a different and context-specific starting point. This observation questions the assumptions of the Cumulative Model. Rather than viewing capabilities as cumulative or sequential, they appear to be interconnected in a more complex and ever-changing network structure. In what follows, we attempt an initial reflection on these observations. It is this network structure that seems to be one of our most important observations and one that leads to a questioning of previous models.

Characteristics that allow context-specificity

First, for managers to understand how they best grow their capabilities, they would need to develop a deeper understanding of their existing capabilities. For this purpose, we discuss and propose four characteristics against which a company's capabilities could be evaluated and ranked. The capabilities are ranked from low to high, in relative terms, along the following four characteristics and relative to each other:

(1) The level of capability interconnectedness

(2) The level of resource adjustment

(3) The level of resource performance intensity

(4) The level of path dependency

Importantly and as an advancement to the legacy models, the definitions of capabilities can look different for each company and their relative rankings along the four characteristics will likely change over time. We detail our thoughts on the four characteristics that help map the operational capabilities in the next paragraphs.

The first characteristic, the *level of capability interconnectedness*, represents the relative number of positive connections and respective strength of linkages a specific capability has with other capabilities. Low capability interconnectedness refers to a relatively isolated capability with few strong relations to others. High capability interconnectedness indicates connection to many other capabilities via relatively strong relationships. If a capability has strong existing relationships with other capabilities (i.e. it impacts or is impacted by other capabilities), it is described as the *base capability*. It is crucial to build it before developing prolificacy in other capabilities. This thought goes along the lines of arguments put forward around quality in the cumulative capability model; yet it must not always be quality.

The second characteristic is the *level of resource adjustment*. It represents the relative number of structural and infrastructural changes required to improve the prolificacy in a specific capability dimension. The necessity for a relatively large number of adjustments to further improve the capability indicates a high level of resource adjustment. Structural input factors concern the managerial, plant and process design decisions, whereas infrastructural input factors are, for example, tangible equipment and facilities (Vastag, 2000). To give practical examples; if your business is oil fracking, improving sustainability capabilities could have a high level of resource adjustment.

The third characteristic, *resource performance intensity*, assesses the relative difficulty of releasing and generating value from a specific capability. Resource performance intensity entails that the magnitude of the immediate performance implication of a capability, once it

has been built, will differ from other capabilities. Low levels of resource performance intensity indicate that it is challenging or takes long for companies to generate value from that capability. High levels, on the other hand, indicate that the capability releases value relatively easily and quickly. Essentially for some capabilities, it is easier to reap the performance benefits and generate immediate value than for others. This refers to immediate performance gains and not to improvements in other capabilities (see capability interconnectedness).

The fourth and final characteristic is the *level of path dependency*. It takes into consideration how dependent the development of a specific capability is on earlier managerial choices. Therefore, it indirectly also includes the time required to improve a capability since higher dependency on earlier choices logically points to a need for significant preparation. Low path dependency indicates that the capability is developed relatively quickly with little necessity for preparing grounds via earlier managerial choices. High levels, however, indicate that the capability heavily depends on earlier choices, offers a restricted set of development paths and is likely to take time to develop. Thus, path dependency is tightly connected to the resource adjustment dimension, but instead of focusing on the structural and infrastructural resources needed, it focuses on past decisions (both regarding operating policies and infrastructure) and how they affect the potential to achieve prolificacy.

Bursting vs merging capabilities

These four characteristics pose our initial thoughts on how one could characterize capabilities. They may help us to understand the overall relationships and hierarchies between capabilities and ultimately lead to an improved description of how modern companies efficiently allocate resources to capability development. A central tenet of what we share here is the configuration of characteristics that makes a capability important in affecting and developing other capabilities within a company.

We conceptualize and visualize this observation by categorizing capabilities into *bursting* vs *merging* capabilities. Bursting capabilities are the starting point for investments whereas merging capabilities should not be used as leverage points. Bursting capabilities help to develop merging capabilities (Figure 2). Thus, a bursting capability is instrumental to develop other capabilities. It is thus in the middle of the Hub-and-Spoke model having high levels of interconnectedness (besides others). A bursting capability has

(1) a HIGH level of capability interconnectedness (i.e. it has strong potentials to affect other capabilities),

(2) a LOW level of resource adjustment (i.e. it requires a relatively small number of adjustments to further improve the capability),

(3) a HIGH level of resource performance intensity (i.e. it releases value relatively easily and quickly) and

(4) a LOW level of path dependency (i.e. it does not depend heavily on earlier choices or requires lots of time to improve).

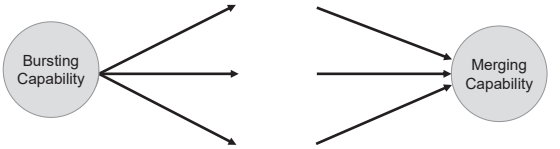


Figure 2.
Bursting vs merging capabilities

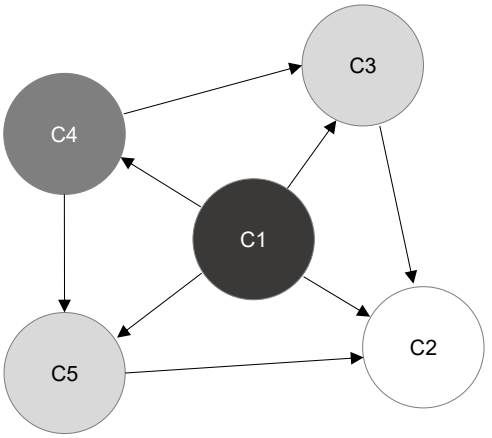
Managers going through the process of assessing their operational capabilities should identify which of their capabilities are bursting or merging and can go on to make better targeted investment decisions with this classification.

Again, these are initial thoughts from our discussions that need to be confirmed empirically. However, if we assume that we are on the right track with this framework, then managers can create their company-specific Hub-and-Spoke View that shapes the development of their capabilities. A thought example is shown in Figure 3. The capability that ranks the highest across all four characteristics is placed at the center of the model (C1); thus, it is centric (a bursting capability). The centric capability is bursting out into the capabilities on the outside, which are peripheral. It is the capability in which resources seem to be most efficiently invested. And on the periphery are the merging capabilities.

Rating the capabilities based on the four characteristics can provide a good snapshot of the interrelations and hierarchies of the capabilities in a particular organizational context. The profile thus allows for company-specific applications tailored to different empirical contexts avoiding reductionist or overly abstract generic models with normative assumptions that do not hold across contexts (Flynn and Flynn, 2004). We believe that depending on the industry's clock speed, regular reassessments are needed.

Pathways: towards rethinking competitive capability building

In this paper, we have tried to show and argue why traditional models for operational capabilities building cannot explain (anymore) why some companies succeed and others fail in efficiently developing their capabilities. We have presented some new insights of thinking about building operational capabilities and shared them with the community in the hope that this will spur new research in this direction. If we as researchers in OM cannot yet properly explain how operational capabilities are best built, then we have not yet answered one of the fundamental questions of our discipline.



Note(s): C indicates a capability. Darker shading indicates a bursting capability with centric positioning; lighter shading indicates a merging capability with peripheral positioning

Figure 3.
A Hub-and-Spoke capability view with five capabilities

We find that the established models cannot reflect that capabilities, either because of recent development or perhaps always, appear to be interconnected in a more complex and ever-changing network structure. We also conclude that no one-size-fits-all model currently can explain the development of operational capabilities. A new model must be flexible enough to take into account the firm-specific context in which capabilities are developed – that is how capabilities are interconnected within the firm, what changes are needed to improve the capability, how difficult it is to unlock the value of a capability and how much the development of a particular capability depends on previous management decisions.

Sustainability as an operational capability: Finally, we do not believe that the ideas of the tradeoff model should be disproven *per se*. While our findings have shown that some of the best companies try and succeed in being good at multiple capabilities at the same time, we still believe that some capabilities are regularly ignored by companies and therefore willingly traded off. We are thinking of environmental and social sustainability. These capabilities are not readily visible to customers, unlike quality, delivery, cost and flexibility. Customers often rely on labels, certificates and company statements, but can rarely feel and experience the company's performance in this area. Future research can therefore be of great benefit to our discipline if it places a special emphasis on the network interaction between the traditional capabilities (quality, delivery, cost, flexibility) and the new capabilities (sustainability, social responsibility) to see and learn how the latter are affected by the former and vice versa. There is no doubt that we need to include sustainability in the new model and think about how it can be developed. To be considered sustainable, companies must perform well in all three dimensions of the "triple bottom line," i.e. social, environmental and economic performance – the pressing issues of sustainability do not allow compromise in this respect and if they do, it will not be at the expense of the environment and society.

Start talking to managers again: We like to think of OM research as practical and applied. However, in recent years we have seen a tendency in scholarly work to engage less with industrial practice. We still rely on the old models of operational capabilities, but the industry has evolved and those models cannot satisfactorily explain the observations we made in leading companies. One of our goals with this Pathway paper is to inspire the OM discipline to go back into companies and talk to managers to gather insights and share them with the community. While it is unlikely that a single study can develop the new model of capability development, we hope that a series of detailed reports will eventually help us identify patterns. Along the way, we hope to motivate colleagues to follow our approach and report their findings. Gaining such insights can only help us develop more accurate theories.

Based on our work with Lufthansa, we have outlined our initial findings about this process. We presented the idea of the Hub-and-Spoke Capability View. Figure 4 shows the four-step process that we think are reasonable to follow when applying the ideas of Hub-and-Spoke Capability View. Our goal with this View was to organize our findings about the dynamic and complex decision to invest in operational capabilities into clear structures.

Adapt to the empirical context of the modern organization: Almost (but not quite) unnecessary to mention is that the organizational context (life cycle, market or industry standards, or technology constraints) is also very likely to play a major role in capability development. So, we should extend our efforts to different industries. Much past research was based on the automotive industry and other large manufacturing companies with strong vertical integration. But value creation is increasingly taking place in less integrated companies. And new value creation models are changing the

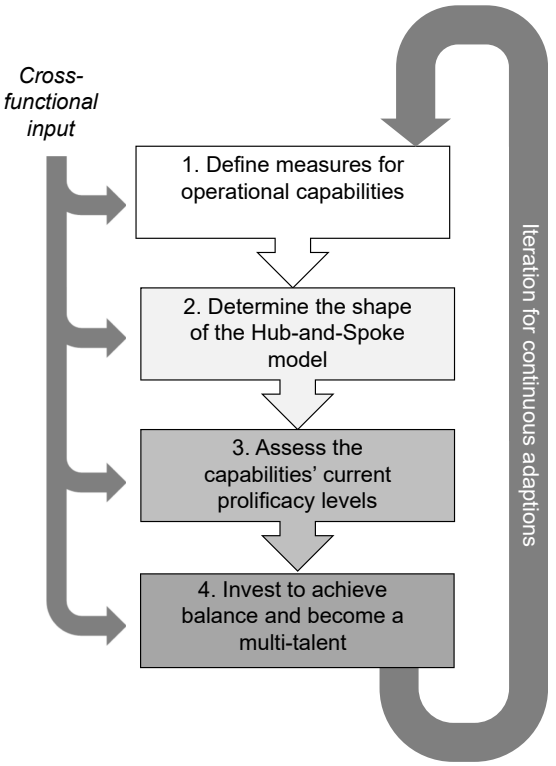


Figure 4.
The four steps for achieving a balanced state of capabilities

rules of business. Digital technologies are driving new business models and the rules of the data economy – the sharing and trading of data – are fundamentally changing industrial production processes. So, when engaging with the industry, we believe that it would be highly valuable to the discipline to engage with less integrated manufacturing industries and services. Particularly the latter have been largely ignored in OM efforts.

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Appendix 1
Overview of literature review

For this literature review, we searched *Decision Sciences, International Journal of Operations and Production Management, Journal of Operations Management, Journal of Supply Chain Management, Management Science, Manufacturing and Service Operations Management and Production and Operations Management*. We used the search terms "competitive capability" OR "competitive priority" OR "cumulative capability" OR "operational capability" OR "manufacturing capability" in a search of titles, abstracts and keywords. We retrieved 111 potentially relevant papers. Among those, 17 did not show a sufficient focus on operations, 36 did not focus on a comprehensive set of capabilities and 30 focused on relevant issues around capabilities that are not central to our research mission. Examples of the latter are micro foundations of operational capabilities in knowledge-based theory (Roscoe *et al.*, 2019), measurement development studies (Krause *et al.*, 2001) and the link between operational and supply chain capabilities (Kim, 2006). Twenty-eight studies passed the screening, out of which nine were dismissed from the sample during further reading, most often due to their lack of discussion of the established conceptual models despite later publication dates.

Source	Focus more on		Arguments/evidence for		Sequence (if applicable)	Mission/main finding	Method	Region(s)
	Prio	Capa	Cumul	Trade-off				
Amoako-Gyampah and Meredith (2007)		x	x		Qual – Cost – Deliv – Flex	Sequence is different in developing countries	Survey	Developing
Boyer and Lewis (2002)	x			x	–	Halo effects may impede measurement of trade-offs among prios	Survey	Developed
Chung and Swink (2009)		x	x		–	Technology use promotes all capabilities but not costs – four different performance groups emerge	Survey	Developed
Ferdows and De Meyer (1990)	x	x	x		Qual – Deliv – Flex – Cost	Suggests the cumulative "sand cone" model as a new theory	Survey	Developed
Ferdows *et al.* (1986)		x	x		Qual – Deliv – Flex – Cost	Projects developments of industries based on the cumulative model	Survey	Developed
Ferdows and Thurnheer (2011)		x	x		Safety – Variability - Codify know-how – Responsiveness - Efficiency	Suggests "fitness" (building capa) as more appropriate concept vis a vis leanness	Field/case	Both
Flynn and Flynn (2004)		x	x		Several	The sequence depends on contingencies like country and industry	Survey	Developed
Größler and Grübner (2006)		x	x		Qual – Deliv – Flex and Cost	Flex and cost are exclusive/ simultaneous depending on the practices applied	Survey	Both
Hallgren *et al.* (2011)		x	x		Qual – Deliv – Cost and Flex (parallel)	Cost and flex do not build on each other, they need a "balanced" co-development	Survey	Developed
Kathuria (2000)	x		x		–	Small manufacturers that focus on all capas achieve higher customer satisfaction	Survey	Developed

(*continued*)

Source	Focus more on		Arguments/evidence for			Mission/main finding	Method	Region(s)
	Prio	Capa	Cumul	Trade-off	Sequence (if applicable)			
Kortmann *et al.* (2014)		x	x	(x)	–	Costs and flex face a trade-off that can be resolved via ambidextrous investments	Survey	Both
Longoni and Cagliano (2015)		x	x		–	Sustainability behaves cumulative to other capas and focusing on all is advisable	Survey	Both
Martín-Peña and Díaz-Garrido (2008)	x		x		–	Prios seem to behave cumulative in a particular strategy aiming at "excellence"	Survey	Developed
Miller and Roth (1994)	(x)	x		(x)	Flex – Qual and Productivity – ?	Maps different emphasis of strategies along the product lifecycle	Survey	Developed
Noble (1997)		x	x			Firms addressing multiple capas are performing better than their competitors	Survey	Developed
Noble (1995)		x	x		Qual – Deliv – Cost – Flex - Innovation	Support for cumulative model and emphasis of the central relevance of quality	Survey	Developed
Pagell *et al.* (2000)		x		x	–	Indicating trade-offs in three companies that are successful in their industry	Field/case	Developed
Peng *et al.* (2011)	x	x			–	Examines fit between innovation and improvement capas and prios	Survey	Developed
Rosenzweig and Easton (2010)	x	x	x	x	–	Trade-offs exist among prios and among management choices, not among capas	Archival/ meta	Both

(*continued*)

Source	Focus more on		Arguments/evidence for		Sequence (if applicable)	Mission/main finding	Method	Region(s)
	Prio	Capa	Cumul	Trade-off				
Rosenzweig and Roth (2004)		x	x		Qual – Deliv – Flex – Cost	Evidence for cumulative, yet job shops may imitate the constraints of an asset frontier	Survey	Both
Schmenner and Swink (1998)		x	x	x	–	Proposes that theories of trade-offs and cumulative capas are not in conflict	Conceptual	n.a.
Safizadeh *et al.* (2000)		x	x	x	–	Differentiates the trade-off discussion with process types – some show them, others not	Survey	Developed
Schoenherr *et al.* (2012)		x	x		–	Capas are more inter-linked and related to performance in developing countries	Survey	Both
Squire *et al.* (2006)		x	x	x	–	Full customization reveals trade-offs and partial customization can resolve them	Survey	Developed
Vastag (2000)		x	x		–	Argues for the higher relevance of the operating frontier based on the RBV	Conceptual	n.a.
Ward and Duray (2000)	x		x		–	Examines capas and performance – only quality affects performance	Survey	Developed
White (1996)		x	x		–	Performance improvement works primarily via costs, which are affected by other capas	Archival/ meta	Both

Note(s): x: set membership; (x): implicit/partial set membership; Prio: Competitive priorities; Capa: Competitive capabilities; Cumul: Cumulative model; Qual: Quality; Deliv: Delivery (or dependability); Flex: Flexibility

Appendix 2

Sources	Operationalization	Congruent element
Cost capability		
Boyer and Lewis (2002)	- Reduce inventory - Increase capacity utilization - Reduce production costs - Increase labor productivity	- Production cost
Chung and Swink (2009)	- Initial purchase costs - Manufacturing overhead costs	- Manufacturing cost
Flynn and Flynn (2004)	- Unit cost of manufacturing	- Cost of manufacturing
Kathuria (2000)	- Controlling production costs - Improving labor productivity - Running equipment at peak efficiency	- Production costs
Miller and Roth (1994)	- The capability to compete on price	–
Safizadeh *et al.* (2000)	- Product cost - Product price	- Product cost
Squire *et al.* (2006)	- Design costs - Manufacturing costs - Component costs - Delivery costs - Service costs	- Manufacturing costs
Flexibility capability		
Boyer and Lewis (2002)	- Make rapid design changes - Adjust capacity quickly - Make rapid volume changes - Offer a large number of product features - Offer a large degree of product variety - Adjust product mix	- Design change - Adjust capacity
Chung and Swink (2009)	- Ability to customize products - Ability to adjust production volumes - Ability to respond to changes in delivery requirement - Ability to produce a range of products	- Customization - Production volumes
Flynn and Flynn (2004)	- Cycle time - New product speed - Product flexibility - Volume flexibility	- Product flexibility - Volume flexibility
Kathuria (2000)	- Introducing new designs or new products into production quickly - Adjusting capacity rapidly within a short period - Handling variations in customer delivery schedule - Handling changes in the product mix quickly - Customizing product to customer specifications	- New designs - Adjusting capacity
Miller and Roth (1994)	- Design flexibility - Volume flexibility	- Design flexibility - Volume flexibility
Safizadeh *et al.* (2000)	- Product variety - Ability to customize	- Customization
Squire *et al.* (2006)	- Operate efficiently at different levels - Operate profitably at different levels - Economically run various batch sized - Vary aggregate output between periods	- Vary output

(*continued*)

Table A1. Overview of operational capabilities definitions and mutual congruence

Sources	Operationalization	Congruent element
Delivery capability		
Boyer and Lewis (2002)	- Provide fast deliveries - Meet delivery promises - Reduce production lead time	- Fast delivery - Meet promises
Chung and Swink (2009)	- Delivery accuracy (correct items were delivered) - Delivery availability (probability that items will be in stock when ordered) - Delivery dependability (delivered on the agreed-upon date) - Delivery speed (short elapsed time)	- Dependability - Speed
Flynn and Flynn (2004)	- On-time delivery - Fast delivery	- On-time delivery - Fast delivery
Kathuria (2000)	- Reducing manufacturing lead time - Meeting delivery dates - Making fast deliveries	- Meeting dates - Fast delivery
Miller and Roth (1994)	- The capability to deliver products quickly - The capability to deliver in time	- Deliver quickly - Be on time
Safizadeh *et al.* (2000)	- Delivery time - Dependability on delivery	- Delivery time - Dependability
Squire *et al.* (2006)	- Speed of delivery - Average lead time - Reliability of delivery times - Percentage delivered on time	- Speed - Reliability
Quality capability		
Boyer and Lewis (2002)	- Capability to provide high performance products - Offer consistent, reliable quality - Improve conformance to design specifications	- Product reliability - Design conformance
Chung and Swink (2009)	- Product overall quality performance - Product features - Product reliability - Product conformance - Product durability	- Product reliability
Flynn and Flynn (2004)	- Process based quality - Market-base quality	–
Kathuria (2000)	- Quality of conformance o Ensuring conformance of final product to design specifications o Ensuring accuracy in manufacturing o Ensuring consistency in manufacturing - Quality of design o Manufacturing durable and reliable products o Making design changes in the product as desired by customer o Meeting and exceeding customer needs and preferences	- Design conformance - Product reliability
Miller and Roth (1994)	- The capability to offer consistent conformance - The capability to provide high performance products	- Conformance quality

Table A1. (*continued*)

Sources	Operationalization	Congruent element
Safizadeh *et al.* (2000)	- Product performance - Number of features on product - Product durability - Product reliability - Product quality consistency - Product quality as perceived by customer	- Product reliability
Squire *et al.* (2006)	- Product durability - Product reliability - Conformance quality - Percentage return defective - Percentage pass final inspection	- Product reliability - Conformance quality
Sustainability capability		
Longoni and Cagliano (2015)	- Social reputation (community) - Employee satisfaction (workforce)	- Social sustainability
Martín-Peña and Díaz-Garrido (2008)	- Minimize repercussion of manufacturing activities on the environment - Manufacture environment-friendly products	- Environmental sustainability
Pagell and Gobeli (2009)	- Harm inflicted to natural systems - Harm inflicted to human systems	- Social sustainability - Environmental sustainability

Table A1.

Appendix 3
Legacy capability development models and key references

History of the legacy capability development models

At the end of the 1960s, the perception spread that manufacturers are forced to make trade-off decisions when developing their capabilities. No single firm can be good at everything at the same time; quality improvements impede per-unit production costs, or flexibility in production can result in quality issues – unless firms have slack, i.e. unused resources, somewhere in their operations. The managerial implications of the trade-off model are that operations managers have to design their operations to be focused and limited to specific tasks with specific performance priorities. Manufacturers needed to decide whether they wanted to be cost leaders, quality leaders, compete on flexibility, deliver, or focus on sustainability. Managers thought they had to focus on one priority at a time because each capability requires different operational structures and infrastructures for support.

However, until today, empirical evidence for the trade-off model has remained sparse. Additionally, as if they intended to falsify the model as quickly as possible, only a few years later, in the 1970s and 1980s, Toyota proved to the world that it is indeed possible to improve quality and flexibility while keeping costs down. This has paved the way for another viewpoint on how the manufacturing capabilities of a firm are related. The trade-off model was followed by the so-called cumulative model. In the cumulative capabilities model, scholars argue that manufacturers can achieve excellence in multiple dimensions at the same time. Ferdows and De Meyer (1990) explain this observation through the sand cone model. They argue that companies can achieve excellence in multiple capabilities if they follow a specific developmental sequence and invest in base capabilities. Similar to building a sand cone, the base (capability) needs to be constantly enlarged while the top (capability) is gradually developed/built. Specifically, they argue that "to build cumulative and lasting manufacturing capability, management attention and resources should go first toward enhancing quality, then-while the efforts to enhance quality are further expanded attention should be given to improve also the dependability of the production system, then and again while efforts on the previous two are further enhanced-production flexibility (or reaction speed) should also be improved and finally, while all these efforts are further enlarged, direct attention can be paid to cost efficiency." This model resonates more closely with managerial practice. Its overall premise that there is a developmental relationship between capabilities and that many companies indeed excel in developing multiple capabilities simultaneously lends credibility to the model's basic assumption.

A summary of premier references in competitive capability research

(1) Skinner, W., Manufacturing: The missing link in corporate strategy. Harvard Business Review, 1969. 47(3): p. 79–91.

Skinner criticizes that manufacturing plays a not large enough role in firm strategizing and suggests that operations should be understood as more than the execution of strategy in manufacturing. Instead, he suggests that firms can compete on their manufacturing capabilities, which face trade-offs among each other. A good manufacturing strategy needs a clear focus on one (or few) competitive capabilities to be successful in the market, according to Skinner.

(2) Ferdows, K. and A. De Meyer, Lasting improvements in manufacturing performance: In search of a new theory. Journal of Operations Management, 1990. 9(2): p. 168–184.

Ferdows and De Meyer suggested the cumulative capabilities model in response to counte revidence for the classical trade-off model. They argue that capabilities are built in sequence, namely, from quality to dependability to flexibility to cost efficiency. They stress that even when the final capability of their "Sandcone Model", cost efficiency, is achieved, "every layer of capability requires continuous attention; one never leaves the necessity of investing in the "basics" of production" (p. 14).

(3) Hallgren, M., J. Olhager and R.G. Schroeder, A hybrid model of competitive capabilities. International Journal of Operations and Production Management, 2011. 31(5): p. 511–526.

Hallgren and colleagues acknowledge the controversial discussion around different sequences of cumulative capability building and, instead of suggesting another sequence, formulate a hybrid model. They use the notion of order qualifiers and order winners to argue that quality and dependability are order qualifiers that work cumulatively (in sequence), whereas cost efficiency and flexibility are order winners that are built in parallel.

(4) Rosenzweig, E.D. and G.S. Easton, Trade-offs in Manufacturing? A Meta-Analysis and Critique of Literature. Production and Operations Management, 2010. 19(2): p. 127–141.

Rosenzweig and Easton examine all available empirical results on competitive capabilities (at the time) to evaluate whether they correlate positively overall (an indication for the cumulative capability model) or negatively overall (an indication for the trade-off model). They find no support for trade-offs among competitive capabilities but, importantly, recognize that managers may still make trade-offs in their managerial goals.

(5) Vastag, G., The theory of performance frontiers. Journal of Operations Management, 2000. 18: 353–360.

Vastag further develops the theory of performance frontiers suggested by Schmenner and Swink (1998; Journal of Operations Management). Vastag argues that a plant's current operational setup (infrastructural choices) is more important than its design (structural choices) to determine whether or not a plant is facing trade-offs. The paper extends the original idea of higher trade-off probability when the operational setup is well done (i.e. close to effective capacity) by discrete changes ("jumps") in the plant's asset configuration (e.g. facility design).

(6) Wu, Z. and Pagell, M., Balancing priorities: Decision-making in sustainable supply chain management. Journal of Operations Management, 2011. 29(6): 577–590.

Wu and Pagell conduct a series of case studies across different industries and record that achieving sustainability is a process of managing and overcoming trade-offs. Firms that take an "equal footing" posture toward economic and sustainability goals (social and environmental) can offer the same price at higher sustainability but will experience lower growth rates in return.

(7) Flynn, B.B. and Flynn, E.J., An exploratory study of the nature of cumulative capabilities. Journal of Operations Management, 2004. 22: 439–457.

Flynn and Flynn explored several unanswered questions from the literature on cumulative capabilities. The authors concluded that it "is not to say that there are not optimal sequences of capabilities; there may be alternative sequences appropriate for different contingencies" (p. 454). Based on our industry experience,

we fully heartedly agree with this observation. In the past, we appear to have largely sidelined the manufacturing capabilities in the development of our models. This has been the motivation for us to offer a new, improved model to show a pathway to firms to become capable multi-talent.

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