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Relating Disaster Response to 'Business-as-Usual': A New Taxonomy of Operations

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1. Introduction

The frequency of large-scale emergencies and disasters is likely to increase over the next fifty years, as a convergence of issues creates ever more favorable conditions for wide-scale disruption. Indeed, supply chain disruptions have been observed as increasing in both frequency and financial severity recently (Hendricks and Singhal 2003) and 'disaster' argued as inevitable in the life of organization (Lin et al. 2006). Appropriately, operations management (OM) scholars have been giving disaster response increasing attention, resulting in a growing body of literature we will refer to as disaster operations management, or DOM, a label intended to include disaster response, crisis management, humanitarian logistics, and emergency services.

The purpose of this study is to develop a new taxonomy for operations, one that clearly articulates the relationship of DOM to its parent domain of OM. This begins in the next section by presenting the argument for *why* OM needs a new taxonomy mapping the diversity of inhabitants within its domain. We then employ the inductive research methodology of iterative triangulation (Lewis 1998) to develop a new taxonomy, which is outlined and discussed in its final form in section 4. This taxonomy suggests that DOM belongs to a distinct sub-domain of OM that it shares with operations such as new product development and film production. Grouping case study evidence from several of these industries reveals intriguing patterns of habits associated with their successful operation, summarized in Section 5. Each of these patterns suggests a research opportunity as underscored in the conclusions of this article, along with the most definitive argument for a new taxonomy: when we better understand the

relationship of disaster response to 'business as usual', our efforts to build the body of knowledge for disaster response ultimately benefits both.

2. Disaster Response and Operations Management

2.1 Problematic Threads through Current DOM Literature

Emergencies and disasters are present throughout the history of human endeavor. If DOM is inclusive of municipal emergency service systems, then this field enjoyed a wealth of development and successful industry applications during the 1970's alone (Green and Kolesar 2004). However, DOM is usually characterized as a new, emerging and/or underdeveloped field (Boin et al. 2010; Boin 2009; Janssen et al. 2010; Kova'cs and Spens 2009). Green and Kolesar (2004) and Tatham and Pettit (2010) cite the turn of the millennium and the events of 2001 as launching this research stream, while humanitarian logistics have been described as 'coming of age' in the aftermath of the 2004 Tsunami (Thomas and Kopczak 2005). Furthermore, this 'new that is not new' is not the only paradox suggested by DOM literature. Reviewing a body of recent DOM studies suggests a set of 'problematic threads', summarized here as patterns of concern over disaster conditions, planning, performance metrics, terminology and lack of a conceptual base. These threads are also reflected in the left-hand column of Table 1.

- INSERT TABLE 1 ABOUT HERE –

2.1.1 Disaster Conditions. One theme found in current literature is an objection that DOM researchers are not paying adequate attention to the conditions and challenges particular to disasters, creating a gap between research and practice (Boin et al. 2010; Altay and Green 2006; Pettit and Beresford 2009; Pedraza et al. 2011; Janssen et al. 2010). Several factors interfere with the applicability of business models to the disaster domain, including inherently high levels of uncertainty (Green and Kolesar 2004), frequent reliance of volunteer effort and ambiguity in

defining the customer (Charles et al. 2010; Pettit and Beresford 2009; Oloruntoba and Gray 2006), as well as the lack of a central planner in an environment often characterized by autonomous actors (Pedraza et al. 2011).

2.1.2 Planning. The role of planning in DOM has been called into question, as it remains unclear how to create plans for the unexpected, particularly without impeding flexibility (Boin et al. 2010). Typically, random elements in operations are assumed to be accompanied by past data from which researchers can construct and validate stochastic models for use in planning. However, Green and Kolesar (2004), Janssen et al. (2010), and Bharosa et al. (2010) all note the natural lack of data from non-routine events, confounding these same efforts in the context of DOM. Planning for the true unknown is characterized as 'intrinsically hard' (Boin 2009), and even the broadest base from which to approach a DOM planning problem can be unclear. As an example, humanitarian supply chains are distinctly project-oriented compared to their commercial counter-parts (Thomas and Kopczak 2005; Charles et al. 2010), although academia tends to treat project and supply chain management as two distinct subjects areas.

2.1.3 Performance Metrics Performance metrics are commonly cited as lacking in disaster response, with numerous calls for remediation by DOM researchers (Boin et al. 2010; Thomas and Kopczak 2005; Altay and Green 2006; Janssen et al. 2010; Beamon and Balcik 2008). One common assumption is that these metrics will be found in the successful practice of business-as-usual, such as Pettit and Beresford's (2009) proposed application of critical success factors from commercial supply chain management to humanitarian aid provision.

2.1.4 Terminology DOM lacks definitive terminology, rendering the meaning of pivotal terms such as 'disaster logistics' ambiguous (Sheu 2007) and giving rise to paradoxical phrases such as 'routine emergency' (Altay and Green 2006). 'Disaster' is, in fact, a political declaration (Altay

and Green 2006; Kova'cs and Spens 2009), although a diversity of published explanations abound, ranging from an event which overwhelms the resources of a single agency (see, for example, Haddow and Bullock 2006) to a distinctly social (as opposed to natural) happening (Dynes 1993).

2.1.5 Lack of Conceptual Base While current DOM scholarship has provided many valuable case studies suggesting best practices, the anecdotal nature of this literature does not yet illuminate why such practices have been successful, and when they might be less so (Thomas and Kopczak 2005). This observation is consistent with calls for more research dedicated to why some businesses fail in the wake of disaster and what distinguishes those businesses from those that don't (Altay and Green 2006). Where case-driven efforts have created a substantial body of valuable DOM findings, Boin et al. (2010) point out that what DOM lacks is a body of theory to relate these contrasting outcomes and better understand the antecedents of effective disaster response.

2.2 Disaster Response within the Larger Domain of OM

Concerns discussed so far all originate from within DOM published research. Additional questions arise when DOM is considered relative to its parent domain of OM.

2.2.1 Established OM Taxonomies and Disaster Response. While one would not expect that every conceptual OM model would provide insight into the particular relationship of DOM within OM, it is of concern that *none* of the models common to OM texts provide this service. As an example, Pettit and Beresford (2009) note how humanitarian supply chains forming in the wake of disasters consist largely of the same processes as their commercial 'business as usual' counterparts, although in operation these two types of systems bear far less resemblance. If two such supply chains were each viewed through the lens of the pervasive 'system perspective'

model illustrated in Figure 1, the analysis would yield largely the same result in either case, as would any rendering of the supply chains as networks of entities, another popular representative of OM.

- INSERT FIGURE 1 ABOUT HERE –

One of the most influential OM taxonomies also appears in Figure 1, the 'product-process matrix' of Hayes and Wheelwright (1979). First appearing in what is now one of the most widely cited journal articles in OM (Pilkington and Meredith 2009), this taxonomy was developed in the context of manufacturing, and thus modern presentations of the model often append 'projects' to the lower right-hand end of its efficient diagonal, expanding the domain somewhat (for example, see Collier and Evans 2007). However, even this revised map of operations does not distinguish disaster response from numerous other endeavors. Increased interest in service systems in the 1980's produced frameworks better suited for comparative analysis in that context, of which the taxonomy of Schmenner (1986) often appears now in service management texts. Also pictured in Figure 1, this taxonomy embodies distinctions similar to the product-process matrix, but clarifies DOM as a 'professional service', nonetheless grouping it with the activities of accountants, lawyers and architects.

2.2.2 Parallel Problematic Threads within the Larger Domain of OM

An earlier theme of paradox deepens when concerns from the narrower domain of DOM are compared to editorials on OM itself. The irony of disasters as 'new' in the context of OM research is reflected in a similar irony that OM struggles with the identity woes of a newcomer, despite the fact that it can trace its roots farther back than sibling business disciplines such as accounting, marketing and finance (Meredith 2001). Critics of OM research argue that it has failed to develop a truly distinct body of knowledge (Pilkington and Liston-Heyes 1999), citing

its fellow business disciplines substantially more than being recognized by them (Linderman and Chandrasekaran 2010), is often perceived as an extension of management science (Meredith 2001), and has shifted its intellectual emphasis at least three times in as many decades (Pilkington and Meredith 2009). Table 1 summarizes how the specific concerns of DOM discussed earlier are likewise reflected in concerns over its parent discipline.

2.3 The Case for a New OM Taxonomy

We propose that the concerns within the domains of DOM and OM are 'two sides of the same coin,' theory being at the heart of both. Theory development is the foundational guide to empirical research (Lewis 1998; McCutcheon and Meredith 1993), building the necessary understanding of a complex phenomenon before deductive study. Finding and implementing measurements in advance of the careful development of their underlying conceptual definitions has been noted as an unfortunate tendency in OM literature, a pattern which weakens research streams with vague and ambiguous results (Wacker 2004). This is of particular concern when considering that DOM researchers have been calling for performance metrics, yet there exists ample evidence that the underlying conceptual foundation on which those metrics would be formed is itself currently weak.

Ironically, other literature suggests that DOM and the broader OM discipline are in fact closely linked. As an example, the influential work of Weick & Sutcliffe (2001) cite 'attention to operations' as one of five practices central to successful crisis management. Meredith (2001) observes that the popularity of OM moves counter to economic stability and prosperity, in that OM captures the most attention during turbulent periods and languishes otherwise. Disasters do appear to thrust operations into the 'limelight' of public attention, and yet the popular framing of OM indicates no logical place for disaster response. Thus, we propose the need for a new OM

taxonomy, one that maps this domain broadly enough to explicitly categorize disaster response, while clarifying how DOM relates to the familiar, better documented industries of 'business-as-usual'.

3. Methodology

This study employs the inductive research technique of iterative triangulation (Lewis 1998), cycling between literature reviews, intuition, and existing case evidence to develop new theory. As a methodology, iterative triangulation is a structured attempt to combine the benefits of each resource base, and is distinguished in particular by the use of existing case studies in new research. In this investigation, activity is organized into three distinct review phases, each which inform the central taxonomy construction phase, as illustrated by Figure 2. A detailed description of the research methodology is located in the Appendix.

- INSERT FIGURE 2 ABOUT HERE -

4. A New Taxonomy for the Domain of Operations Management

4.1 Taxonomy Framework

Construction of the finished taxonomy is outlined here in four propositions, employing the conceptual definitions listed in Table 2. This list begins by specifying the unit of analysis, a 'system' or group of elements with some unifying purpose. The most important choice in the further design of a taxonomy is selection of the variables that define its classification scheme (Bozarth and McDermott 1998; Miller 1996), specified here in the first proposition.

- INSERT TABLE 2 ABOUT HERE -

4.1.1 New Taxonomy Proposition 1. *Any system can be subdivided into two distinct sets of contributory elements, those which are tangible and those which are intangible.* This delineation is not new, having a long history as a distinction central to an understanding of goods versus

services. However, where tangibility historically describes output, this framework deliberately excludes final products from consideration and focuses on the system itself. As an example, the successful operation of a factory involves tangible elements such as workers, machinery and supporting infrastructure, as well as intangible elements such as processes and environmental influences.

4.1.2 New Taxonomy Proposition 2. *Any element of a system can be measured for 'system's cognizance', or 'cognizance' for convenience. Cognizance refers to the degree of information concerning the element that is available prior to production.* As an observable attribute, cognizance is anchored by two extremes, proposed as 'prescribed' versus 'emergent' in Table 2. A highly prescribed element is one whose particulars are known to the system well in advance of any use, such as a certain machine on an assembly line. In contrast, a highly emergent element is not known to the system until it manifests itself during production, such as a volunteer at the site of a disaster. A single taxi cab would represent a tangible element in some intermediate state of cognizance, in that its identity and capabilities are known to the dispatch taxi system, but the particulars of its location or immediate availability cannot be projected precisely well in advance of need for its contribution.

4.1.3 New Taxonomy Proposition 3. *Any set of elements within a system can be measured for system's cognizance, by aggregating the individual measurements of those elements in that set.*

It is the aggregated measures of the element sets that define the new taxonomy. Like its component elements, each set is expected to measure at some point along the cognizance spectrum, with Figure 3 providing example characteristics that may be associated with varying levels of cognizance in the case of tangible and intangible sets.

4.1.4 New Taxonomy Proposition 4. *Contrasting the system's cognizance of tangible versus intangible elements provides a taxonomy that suggests four distinct system types.* This resulting matrix is illustrated in Figure 4, with the proposed conceptual definitions of each system type summarized in Table 3.

- INSERT TABLE 3 ABOUT HERE –

- INSERT FIGURE 4 ABOUT HERE –

4.2 Four Sectors and Four OM System Types

The taxonomy is presented as a four box model here because this is the minimum level of complexity necessary to distinguish disaster response from 'business as usual', the over-arching goal of this study.

4.2.1 Prescriptive Systems. Sector I, the upper left-hand category in Figure 4, suggests systems whose contributory elements, tangible and intangible, are well known in advance of production. This implies a high degree of both certainty and control, allowing thoughtful choreography of activity, presumably through advanced planning and optimization. Figure 5 suggests logical foci for each sector of the taxonomy, including these 'prescriptive' systems. Such systems can be expected to share a focus on the efficient replication of design, be it the literal replication of a mass manufactured product or the execution of carefully scripted plans and agreements.

- INSERT FIGURE 5 ABOUT HERE -

4.2.2 Compliant Systems. Sector II, the upper right-hand quadrant in Figures 4 and 5, suggests a system which operates from an enduring organizational base but whose conditions and actions are driven by circumstance. Thus, the term 'compliant system' is proposed for this sector, as these are systems which seek the efficiency of installed design but presumably comply with diverse customer requirements during operation, such as hospitals, industrial job shops or the

courier airline service suggested in Figure 5. Compliant systems can be described as 'make-to-order', focusing on successful order fulfillment in a dynamic and even turbulent environment.

4.2.3 Swarm Systems. Similar to Sector II, Sector III suggests a hybridization of the emergent and the prescribed, but these 'swarm systems' differ in that little is known about their tangible base in advance of production, making them the setting of temporary or spontaneous organization. Sector III seeks efficiency by standardizing and choreographing the intangible interactions of an otherwise fluid set of tangible contributors, allowing a shifting group to achieve some common goal. The internet is an example swarm system, as its tangible infrastructure is driven moment-by-moment through the individual choices of a vast group of autonomous participants, all forming a functional network through the repeated application of standardized connecting protocol. The idea of reliable self-organization has been gaining attention with advent of the internet (see, for example, Gloor and Cooper 2007), but swarm systems are not restricted to this setting. Keeping with a theme of aviation, Figure 5 suggests air traffic control as an example swarm system, as this operation spontaneously and yet reliably coordinates the simultaneous use of airspace and airport infrastructure by multiple participants.

4.2.4 Emergent Systems. Finally, the lower right hand corner of Figures 4 and 5 delineates a system comprised primarily of emergent elements, both tangible and intangible. As the classification suggests, emergent systems are operations whose physical components and intangible conditions and actions are all driven by circumstance. Logically, this system might appear the least efficient of the four operational forms, as it strives to comply with a turbulent environment while working from a temporary and shifting base of contributors. Emergency and disaster response are examples from this sector, such as the aerial wild land fire fighting operation suggested in Figure 5. However, while disaster response exemplifies the creation of an

emergent system, this taxonomy does not imply that emergent systems are exclusive to emergencies and disasters.

4.3 Demonstrating the New Taxonomy with Established Taxonomies

As Figure 6 illustrates, the iconic 'diagonal' of the product/process matrix of Hayes and Wheelwright (1979) logically maps across the top of the new taxonomy. Here the tangible base of the system is largely prescribed, an expectation of the manufacturing domain from which the original matrix was developed. Similarly, the service process matrix of Schmenner (1986) can be overlaid on the new taxonomy with intriguing resonance, even though the defining variables of the older framework differ. As seen earlier in Figure 1, the vertical scale of the service process matrix is 'degree of labor intensity', which could be expected to increase between increasingly emergent tangible element sets, provided that the only source of growing emergence was decreasing reliance on machinery. Once greater degrees of emergence are created by contributors moving freely in and out of the set, this parallel measure of labor intensity is not likely to continue increasing. Thus, the service process matrix was arguably intended to frame services provided within permanent organizations, mapping the upper half of the new framework.

- INSERT FIGURE 6 ABOUT HERE -

Figure 6 also suggests how the industrial versus artful management models of Austin & Devin (2003) can be re-interpreted as a map of contrasting practices defining the diagonal between prescriptive and emergent systems. This analogy will be discussed in more detail later.

5. Relating Disaster Response to 'Business-as-Usual': Observing the Emergent Sector

Of the four sectors visible in Figures 4 and 5, the two with the least relation to one another are the prescriptive and emergent sectors. While each share a transition into compliant and swarm,

their centers represent polar opposites of rich knowledge and strong control versus extreme uncertainty and poor control. Assuming OM cannot trace its history as a formal discipline any earlier than management itself, then this history arguably begins no earlier than the late 19th century, with the advent of 'scientific management' in manufacturing. Logically, the OM discipline will have built up the largest body of knowledge in the sector where it has been at work the longest, and would have the strongest current understanding of how best to operate under those conditions. This reasoning points to the prescriptive and compliant sectors.

Since this taxonomy only recognizes cognizance of elements and not the actual elements themselves, the contrast between prescriptive and emergent is consistent with commentary such as commercial and humanitarian supply chains consisting of largely the same processes, yet little being understood about how humanitarian supply chains operate (Pettit and Beresford 2009). Although commercial and humanitarian supply chains consist of largely the same logistical elements, they are identified as two very different systems by the new taxonomy, implying that successful operation of one will not likely translate directly into best practices for the other.

5.1 Inhabitants of the Emergent Sector

A range of examples from the emergent sector can be readily identified through the fact that they would each be temporary in some sense. This commonality is deduced from the sector's definition, in that if an emergent system endured through time, it would accumulate a history of at least some of its elements, enabling cognizance to improve and arguably shifting that system into an adjacent sector. Interestingly, discussion here will tie new product development to the emergent sector, which implies an analogy between the product life cycle model (Hayes and Wheelwright 1979) and the new taxonomy: as some emergent systems age, they logically transition into more prescriptive (and presumably efficient) forms.

Temporary organizations are the subject of increasing interest in organization science (Bechky 2006), with the recent review of Bakker (2010) citing theatre, building construction, software development, emergency response, film making, advertising, consulting and biotechnology (new product development) as examples. However, while emergent systems can be expected to manifest as temporary organizations, not all temporary organizations are strongly emergent. Advertising and consulting are professional services as identified by Schmenner (1986), more appropriately associated with the border between emergent and compliant, while the habitual activity and more predictable environment of building construction suggests a position on the border between emergent and swarm. Figure 7 shows proposed groupings of the remaining examples of Bakker (2010) in a detailed view of the emergent sector, an example of each being featured in later discussion.

- INSERT FIGURE 7 ABOUT HERE -

Retrospectively, the relationship between disaster response and some creative enterprises should not be surprising, as it has been voiced before. For example, Charles et al. (2010) report a UN chief of logistics as describing some humanitarian delivery systems as 'imaginative and unconventional' by necessity, while Bigley and Roberts (2001) quote emergency responders speaking openly of the need for 'improvisation'. Bechky and Okuysen (2011) pair together police SWAT teams and film production crews to further underscore the theme of improvisation in operation, while Austin and Devin (2003) show the commonality between theatre production and agile software development. Austin and Devin (2003) hypothesize that that the latter two cases represent a general phenomenon they dub 'artful making', described as relying on emergence.

5.2 Tactical Threads from the Emergent Sector

During taxonomy development, groups of case studies from differing organizations were examined for common and/or contradictory observations, to strengthen or refute the current form of the taxonomy. One result from the final iteration of development was a set of 'tactical threads' between eight cases drawn into the process, as delineated in Table 4. Tactical threads are patterns of practice visible in the combined case study evidence, and two such threads- temporary organization and improvisation- have been incorporated into earlier discussion. Table 4 outlines four additional patterns, discussed here in conjunction with related literature.

- INSERT TABLE 4 ABOUT HERE -

5.2.1 Simultaneity of Command and Collaboration. One enduring paradigm of organization science holds that hierarchical organizations will falter relative to organic network structures when exposed to turbulent and ambiguous environments (Bechky 2006; Adler et al. 1999), including disaster response (Janssen et al. 2010). One compelling feature of the case studies here is that they neither support nor refute this paradigm because most of the organizations appear to deliberately maintain *both* structures simultaneously. Indeed, one of the principle findings of Bigley and Roberts (2001) is that the Incident Command System used by emergency responders is in fact a new organizational form, one that fuses the efficiency of centralized control with the flexibility of 'constrained improvisation' throughout its ranks. In studying Waffle House Restaurants' food service in the immediate aftermath of hurricanes, Ergun et al. (2010) notes how the appointment of a 'commander-in-control' signals that Waffle House is shifting into its disaster mode, yet a key feature of that mode is the granting of disaster-related decision making authority to anyone at the site of the disaster. Although current thinking generally holds that hierarchical relationships stifle improvisation (Boin et al. 2010), the case

studies of Bechky (2006), Stuart and Tax (2004), and Austin and Devin (2003) all highlight the significance and centrality of the director in filming and theatre, settings that are otherwise quite 'flat' with intense group collaboration.

This theme is echoed in recent studies of new product development, such as Tatikonda and Rosenthal's (2000) findings that a balance of 'firmness and flexibility' is most closely associated with the success of such projects, where formality governs the overall project structure while flexibility permeates the endeavor throughout its work level. Similarly, studies of virtual teams in software development indicates the combined use of Theory X (command) and Theory Y (collaborate) managerial approaches by team leaders yields the best results (Thomas and Bendoly 2009; Thomas and Bostrom 2008). In all these studies, the researchers comment that their findings are distinctly contrary to the traditional assumption that such approaches are mutually exclusive.

Coordination is typified as nothing less than the 'holy grail' of DOM (Boin et al. 2010), 'undisputed' in its centrality to successful response (Janssen et al. 2010). Failure to recognize a new form of coordination is one possible explanation for the ambiguity suggested by current research on this issue. For example, Bharosa et al. (2010) notes finding no clear organizational style among disaster relief agencies, as some appear highly hierarchical in their practices, and others less so. Other findings from disaster management studies indicate that top down 'command-and-control' is helpful in a response, but there exists a simultaneous need for 'bottom up' coordination (Boin et al. 2010). In either form, this coordination isn't always evident in large-scale humanitarian responses, as the question of 'who is in charge' sometimes results in 'the battle of the Samaritans,' as well-meaning aid agencies sometimes struggle to align their actions during initial response (Boin et al. 2010; Altay and Green 2006). Although the issue of

coordination in this context is inter-organizational, as opposed to the primarily intra-organizational examples of the case evidence group, we propose that research to advance understanding of this 'fused' form of coordination offers a powerful means for OM scholarship to assist these agencies in their creation of future emergent systems.

5.2.2 Prescribing Rules and Breaking Them. Another intriguing pattern from the emergent sector is an emphasis on the use of protocols, accompanied by deliberate provision for discarding them. Protocols are highly prescriptive rules governing work flow and decision making, often found by that name in situations such as the rapid treatment of trauma patients. In that setting, Faraj and Xiao (2006) highlight both reliance on protocol and active provision for breaking protocol as central to successful coordination. Similarly, Bechky and Okuysen (2011) note that film crews and police SWAT teams share a group understanding of distinctly standardized work flows, vital to both the swift completion of that work and to the group's ability to successfully break and re-configure these prescribed routines in the presence of unexpected developments. Simpson (2006) demonstrates how the standard operating procedures ('SOPs') governing structural fire fighting are detailed enough to be analyzed as complex project networks. In the United States, however, fire departments are often advised to re-label their protocols from 'SOPs' to 'SOGs', or standard operating guidelines, to protect against lawsuits over any deviation from their published rules (for example, see IOCAD Emergency Services Group 1998). In fact, such deviations are usually necessary and natural outcomes of the more improvisational aspect of fire fighting, as observed by Bigley and Roberts (2001).

5.2.3 Iterative Planning. Boin (2009) observes that the pace, complexity and ambiguity of an unfolding disaster can overwhelm 'normal' modes of assessment and planning. Another pattern visible in both DOM and non-DOM emergent case evidence is a 'not so normal' habit of

planning in rapid iterative cycles, pursuing planning and production simultaneously. Ergun et al. (2010) describes Waffle House Restaurants hurricane response plan as organized into 'waves', the first wave being supplies and activities prescribed from past experience, setting the stage for planning the next logistical wave from feedback during the first wave's implementation. Described as critical to 'managing when you don't know where you're going', Austin and Devin (2003) frame these iterations as deliberate regular 're-conceiving' of the endeavor by the theatre companies and software developers they observed. Stuart and Tax (2004) observed theatre's particular reliance on integration of 'systemic testing' into the routine meetings that mark its iterative cycles. This on-going habit of evaluation well before any assessable final outcome is hypothesized to reveal flaws before they can manifest in the final product, and is remarkably evocative of the 'pause and learn' process now practiced at NASA's Goddard Space Center, likewise requiring teams to reconvene planning meetings at each project milestone, as opposed to following one plan and debriefing the project as an outcome (Madsen et al. 2011).

5.2.4 Open Forums as Decision Support. Information technology (IT) has long been credited as central to the success of disaster response, although telecommunication is featured heavily in practice and sophisticated IT-based decision support systems (DSS) far less so (Pettit and Beresford 2009). Researchers have noted the multi-agency nature of large scale responses is an inherent obstacle to the development of DSS (Boin et al. 2010; Green and Kolesar 2004), but the case studies here suggest an additional factor may be complicit in the seemingly slow evolution of practical DSS for disaster response. When comparing emergent systems of varying descriptions, another pattern between them is a preference for unstructured 'open forums' for communication, accessible by anyone involved in the undertaking. These open forums are apparent in emergency response as short-wave radio channels used by all responders, the same

technology that Bechky (2006) notes as supporting intensive, continual communication of multiple parties during film production. Austin and Devin (2003) cite the importance of open forums to successful theatre production and software development, although here the forum is one consolidated workspace in which all parties communicate face-to-face, similar to the intensive verbal exchanges of multiple experts during the rapid treatment of a trauma patient observed by Faraj and Xiao (2006).

In the typology of networks, all these forums are considered 'all channel' communication networks, representing the lowest degree of centrality in communication flow (Therrien 1995). This reliance on all channel communication may be related to another phenomenon observed across 'high-reliability' organizations such as fire fighting brigades, the distinct need to maintain a 'shared view' of the current situation (Bigley and Roberts 2001; Bechkly 2006). Regardless, it is important to note that these open forums are themselves a form of decision support, one that appears relevant to success under these conditions. As work continues on developing more sophisticated DSSs for disaster response, it may be that the first systems successful in practice will bear little resemblance to DSSs in commercial settings, dedicated instead to the intelligent fostering of otherwise unstructured exchanges.

6. Conclusions and the Case for Further Study of the Emergent Sector

This investigation sought to reconcile disaster response with the broader domain OM at the conceptual level only. Having been formed through inductive reasoning, its resulting taxonomy now invites refutation by deductive efforts. This 'empirical riskiness' of taxonomy is one trademark of good theory (Wacker 1998). If, in exploring measurable properties to characterize cognizance of the tangible and intangible, researchers can then demonstrate operations of

distinctly dissimilar configurations grouping closely within the taxonomy's domain, its validity as a map of OM is disproven.

Assuming that the new taxonomy is not refuted in future empirical study, we wish to emphasize two reasons why OM researchers should take particular interest in its emergent sector. First, the domain of operations management already includes significant industries whose leaders and managers possess very little direct control, including highly entrepreneurial activities. In contrast to OM's 'instinctive desire to control' (Hayes 2002), emergent systems rely instead on relevant improvisation. New research opportunities lie in the explicit recognition of improvisation and in the investigation of what factors foster successful improvisation in OM. Each of the case study 'threads' here suggests an informal hypothesis concerning such, and further research may uncover more. In addition, any prescriptive (or compliant or swarm) system may be abruptly transformed into an emergent system by damage to its prescribed elements. Understanding the successful operation of an emergent system provides teachable lessons to managers in more prescribed environments on best practices to adopt during crisis, in contrast to their best practices under normal conditions. Certainly, there remain multiple promising research opportunities to bolster the body of knowledge in this sector, work that benefits both the industries that habitually deal with emergence, and any other industry that might experience it unexpectedly.

Appendix: Methodological Process

This section provides the details of the methodological process employed in this study, beginning with statement of the initial assumptions that framed the inductive effort from its inception, and proceeding with detailed descriptions of the work phases illustrated in Figure 2.

Guiding Assumptions

The active pursuit of a new taxonomy began with three a priori assumptions. These assumptions were drafted largely to align the development process with specific virtues of 'good theory', as discussed in detail by Wacker (1998). These assumptions are:

- **The taxonomy's unit of analysis would be that of a 'system,' or a set of elements with a unifying purpose.** Elements could be considered the smallest component entities necessary to describe the origins of some outcome of interest, presumably the provision of some good or service.
- **The new taxonomy would ideally require at most two variables for successful relation of any system to any other system.** This pursues the 'parsimony' feature of good theory.
- **The new taxonomy must logically relate to the most popular established frameworks in OM.** While these earlier taxonomies have failed to adequately characterize disaster response in the broader context of OM, it is held as self-evident that their long service in both research and teaching profoundly validates them. Conclusions from the new taxonomy are therefore required to be consistent with these earlier insights while simultaneously providing some new insight, as embodied in the virtues of 'uniqueness', 'conservatism' and 'fecundity' inherent in good theory.

Work within the investigation was organized into four distinct phases, although the term 'phase' in this setting is meant only as a bounded sub-set of activity within the investigation as a whole, and does not imply chronological sequence.

Configurations Phase. Initially, this phase consisted of a page-by-page audit of thirteen introductory OM textbooks, creating an inventory of the taxonomies and broad conceptual

frameworks employed in each book. The combined sales of this sample group comprise the majority of textbook adoptions for Introductory OM classes in the United States. The most common taxonomies were traced back to their original publication when possible, allowing examination of subsequent citations to draw out 'descendent commentary' and related modifications. These results were used to both build the case for a new taxonomy and to test the consistency of same.

Disaster OM and Related Literature Phase This phase originally consisted of a review of recent DOM literature, to compile the patterns of concern discussed early in this paper. Later it became apparent that at least some of the insight necessary for a new taxonomy resided outside of OM, primarily organization science. As with all other phases, *Web of Science* ® served as the primary search engine. Patterns were clarified through the creation of 'scratch sheets' dedicated to the suspected threads, where supporting statements from various papers were compiled verbatim for combined review. This methodology was followed in the review of the OM theory phase and the case study evidence reviews during taxonomy construction.

OM Theory Phase Originally thought to be a simple service module to locate discussion of the most highly cited OM frameworks, the scope of work in this phase likewise expanded mid-investigation to include search and synthesis of published commentary in OM journals on the state or future of the OM discipline itself, as was summarized earlier in Section 2 of this paper.

Taxonomy Construction Phase. The iterative elements of this study were associated with taxonomy development, as each cycle began with the selection of potential classification variables, informed by the findings of the literature reviews. Candidate variables were first vetted by the eight rules of good conceptual definitions, as specified by Wacker (2004). This comprised a failure point for many candidates, resulting in the selection of more variables.

Classification variables that did pass, however, defined a potential taxonomy to be tested next for any contradiction or dissonance with the frameworks of Hayes and Wheelwright (1979), Shmenner (1986) or Austin and Devin (2003). Should the potential framework pass that test, a minimum of three case studies were selected, comprising non-disaster or non-emergency industries that would be closely associated with disaster response in the current framework. These case studies were pooled with at least three case studies from existing DOM literature, and tactical observations across the group were then examined for patterns and instances of contradiction.

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Table 1 Reflected Research Concerns within the Domains of Disaster Operations Management and General Operations Management

Disaster Operations Management (DOM)	General Operations Management (OM)
poor understanding of disaster conditions/ use of ill-fitting assumptions from outside disaster domain (Boin et al. 2010; Altay and Green 2006; Charles et al. 2010; Pettit and Beresford 2009; Green and Kolesar 2004; Pedraza et al. 2011)	OM researchers' tend to seek and/or frame problems to fit a desired research technique (Hayes 2002; Bozarth and McDermott 1998)
existing DOM research heavily favors mathematical programming (Altay and Green 2006; Simpson and Hancock 2009)	OM is often perceived as applied Management Science (Meredith 2001) Despite its roots in complex phenomena, case studies are less common in OM research (Linderman and Chandrasekaran 2010)
DOM lacks performance metrics (Boin et al. 2010; Thomas and Kopczak 2005; Altay and Green 2006; Janssen et al. 2010; Beamon and Balcik 2008)	OM currently emphasizes measurement over development of concepts from which to form meaningful metrics (Wacker 2004) OM lacks adequate metrics for reliability and responsiveness (Hendricks and Singhal 2005a, 2005b)
OM problems in disaster settings are more project-based than their commercial counterparts (Thomas and Kopczak 2005; Charles et al. 2010; Simpson 2006)	OM in practice is more project-oriented its traditional focus on process management (Hayes 2002) current management practices (or 'industrial making') emphasize replication of well-defined products and are less applicable to complex and creative projects (Austin and Devin 2003)
DOM researchers usually assume a central planner while disaster response is usually implemented through a temporary network of autonomous players (Pedraza et al. 2011; Simpson and Hancock 2009)	OM traditionally focuses on the single business unit while modern practice often requires networks of players (Hayes 2002) OM understanding of complex organizational phenomena is held back by lack of adequate theoretical frameworks of same (Boyer et al. 2000; Bozarth and McDermott 1998)

Table 2 Key Formal Conceptual Terminology of Proposed OM Taxonomy (Proposed Definition in Bold-faced Font)

Concept	Role	Definitions, Conceptual and Common	Synonyms***	Examples
system	unit of analysis	**A group of elements with a unifying purpose.** "…a group of units so combined as to form a whole and to operate in unison." * "… group, set, or aggregate of things, natural or artificial, forming a connected or complex whole." **	operation endeavor organization network	factories projects supply chains businesses
tangible element	variable	**A system component with physical presence.** (tangible) "…substantially real; material." * "…physical and material assets which can be precisely valued or measured." ** (element) "…a constituent part." * "…a component part of a complex whole." **	input contributor resource processor participant agent actor	employees equipment materials facilities fleets customers volunteers
intangible element	variable	**A system component lacking physical presence.** (intangible) "…incapable of being touched; impalpable." * "…not tangible; incapable of being touched; not cognizable by the sense of touch; impalpable."**	action interaction transformation conversion conditions	demanding welding packaging transporting collaborating
cognizance	variable state	**Degree of system's knowledge.** "…apprehension by the mind; awareness." * "…to be aware of, know by observation or information." **	certainty awareness	information telemetry
prescribed	variable state scale anchor	**Completely known in advance of production.** "…laid down as a guide or rule of action."* "…laid down or fixed beforehand; ordained, appointed, decreed; set, defined." **	deterministic defined known designed proactive	controlled scheduled automated integrated standard
emergent	variable state scale anchor	**Unknown until production.** "…rose, came forth, or came into view." * "…that arises from or out of something prior; consequent, derivative." **	random spontaneous unknown contingent reactive	improvised ad hoc autonomous custom impromptu

* *The Merriam-Webster Dictionary* (2004), F.C. Mish, Ed. Merriam-Webster Incorporated, Springfield, MA.

** *The Oxford English Dictionary, 2nd Edition* (1989), J. Simpson and E. Weiner, Eds. Oxford University Press, Oxford, UK.

*** The terms listed as ‘synonyms’ also represent concept labels tested in earlier iterations of the proposed taxonomy.

Table 3 Proposed Terms to Delineate the Four System Types within OM Taxonomy

Term	Definition	Synonyms***	Examples
prescriptive	"…serving to prescribe." * "…that prescribes or directs; giving definite, precise directions or instructions." **	make-to-stock feedforward industrial	mass manufacturing oil refining commercial passenger airlines
compliant	"… a disposition to yield."* "…complying, disposed to comply; ready to yield to the wishes or desires of others."**	make-to-order feedback job shop	commercial printer hospital machine shop
swarm	"…to throng together."* "…a very large or dense body or collection; a crowd, throng, multitude."**	react-to-stock collective assimilative	crowd-sourcing internet traffic air traffic control
emergent	"…rose, came forth, or came into view." * "…that arises from or out of something prior; consequent, derivative." **	react-to-order contingent artful	disaster response creative ensembles rapid product development

Sources:
* *The Merriam-Webster Dictionary* (2004), F.C. Mish, Ed. Merriam-Webster Incorporated, Springfield, MA.
** *The Oxford English Dictionary, 2nd Edition* (1989), J. Simpson and E. Weiner, Eds. Oxford University Press, Oxford, UK.
*** The terms listed as 'synonyms' also represent concept labels tested in earlier iterations of the proposed taxonomy, but declined in favor of the proposed term.

Table 4 Tactical Threads from Emergent Sector Case Studies in Final Iteration of Taxonomy Development

Thread	**Austin & Devin 2003** (theatre & software development)	**Bechky 2006** (film crews)	**Bechky & Okhuysen 2011** (film crews & police SWAT teams)	**Bigley & Roberts 2001** (fire fighting/initial disaster response)	**Ergun et al 2010** (humanitarian logistics)	**Faraj & Xiao 2006** (emergency room trauma teams)	**Simpson 2006** (structural fire fighting)	**Stuart & Tax 2004** (theatre)
Simultaneity of Command & Collaboration	**X**	**X**		**X**	**X**	x		**X**
Prescribing Rules & Breaking Them			**X**	**X**	x	**X**	x	
Iterative planning	**X**		x		x	**X**	**X**	**X**
Open Forums as Decision Support	**X**	**X**	x	x		**X**		

X = definitive discussion and/or finding in case study evidence
x = related discussion and/or similar theme in case study evidence
A blank signifies no discussion and no contradictory observations in the case study evidence. The lack of contradictory observations is indicative of the fact that this grouping is the result of the final iteration of taxonomy development. (See Appendix for more detail.)

FIGURES

Figure 1 Traditional frameworks of operations management

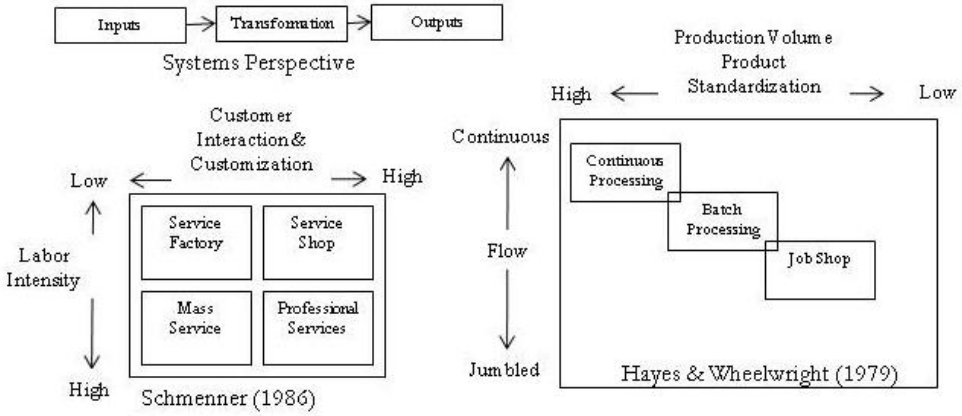

Figure 2 Methodological process

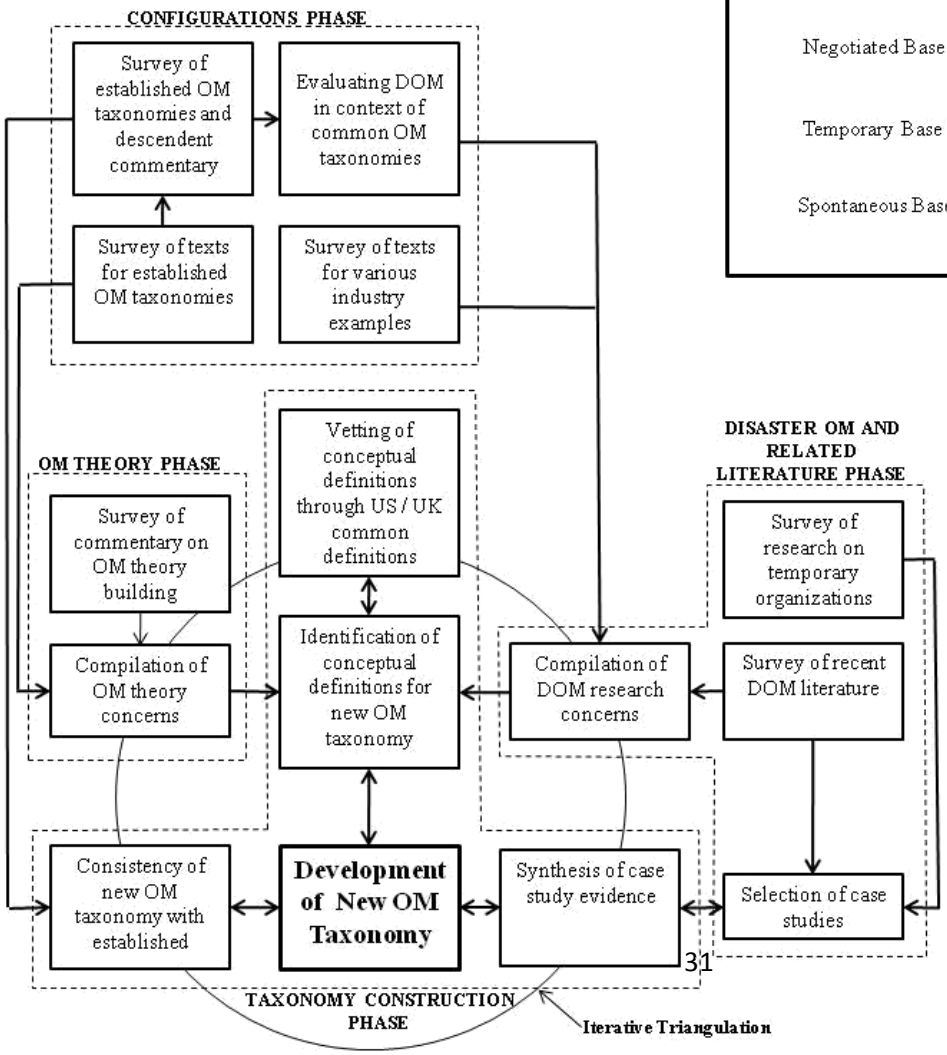

Figure 3 Example characteristics of tangible and intangible element sets at varying levels of cognizance

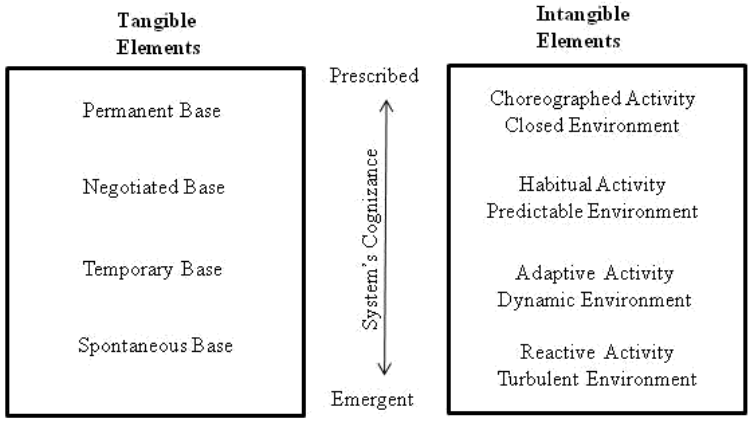

Figure 4 Proposed taxonomy of operations management

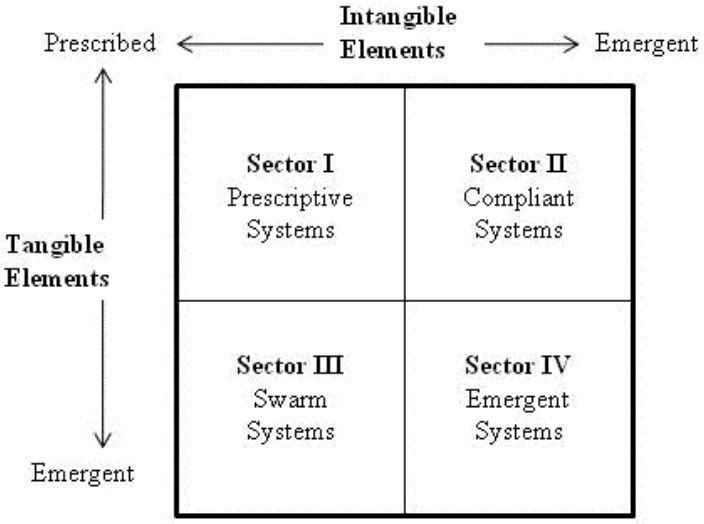

Figure 5 Proposed taxonomy sector foci with examples

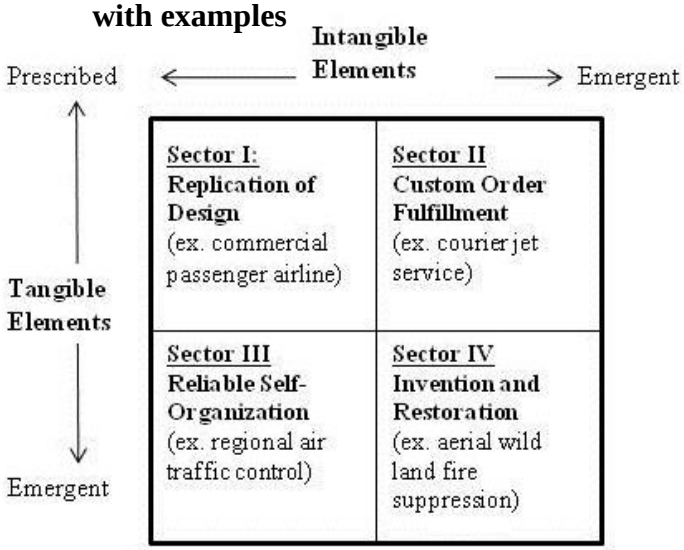

Figure 6 Mapping of existing frameworks against new OM taxonomy framework

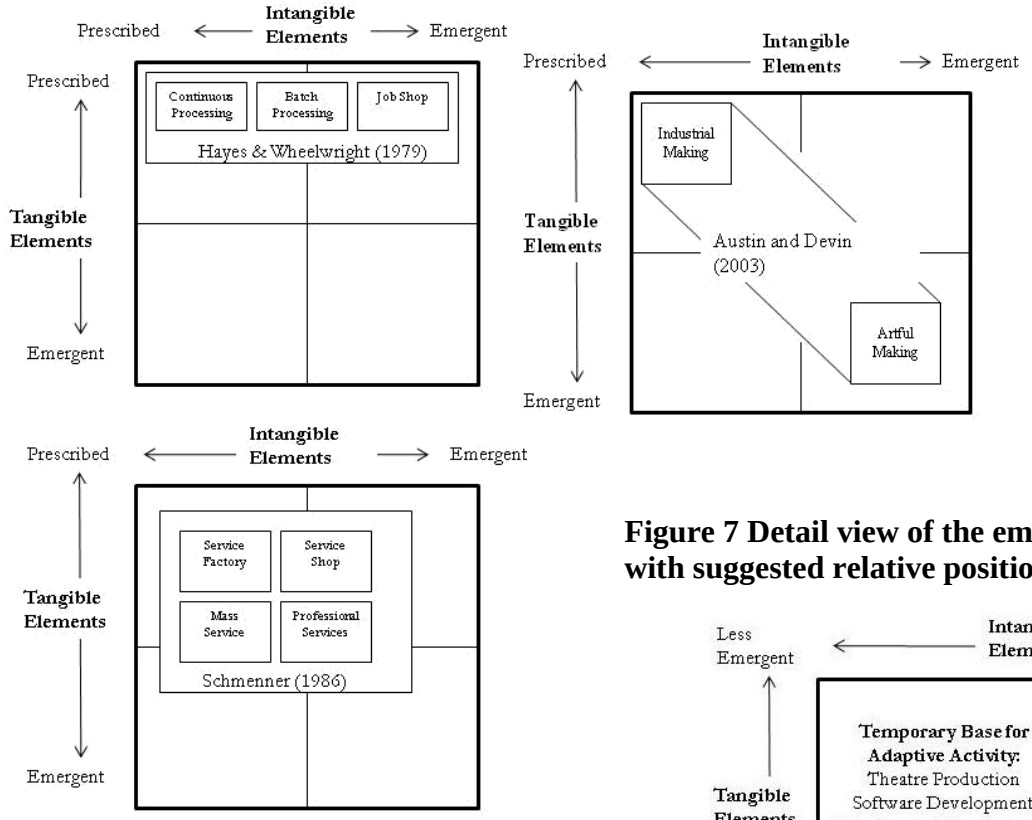

Figure 7 Detail view of the emergent sector of new taxonomy, with suggested relative positioning of examples