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Development and Validation of a Mass Casualty Conceptual Model

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Abstract

Purpose—To develop and validate a conceptual model that provides a framework for the development and evaluation of information systems for mass casualty events.

Design—The model was designed based on extant literature and existing theoretical models. A purposeful sample of 18 experts validated the model. Open-ended questions, as well as a 7-point Likert scale, were used to measure expert consensus on the importance of each construct and its relationship in the model and the usefulness of the model to future research.

Methods—Computer-mediated applications were used to facilitate a modified Delphi technique through which a panel of experts provided validation for the conceptual model. Rounds of questions continued until consensus was reached, as measured by an interquartile range (no more than 1 scale point for each item); stability (change in the distribution of responses less than 15% between rounds); and percent agreement (70% or greater) for indicator questions.

Findings—Two rounds of the Delphi process were needed to satisfy the criteria for consensus or stability related to the constructs, relationships, and indicators in the model. The panel reached consensus or sufficient stability to retain all 10 constructs, 9 relationships, and 39 of 44 indicators. Experts viewed the model as useful (mean of 5.3 on a 7-point scale).

Conclusions—Validation of the model provides the first step in understanding the context in which mass casualty events take place and identifying variables that impact outcomes of care.

Clinical Relevance—This study provides a foundation for understanding the complexity of mass casualty care, the roles that nurses play in mass casualty events, and factors that must be considered in designing and evaluating information-communication systems to support effective triage under these conditions.

Keywords

Informatics/information technology; theory construction; care delivery system; public health

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Recent events, such as the 2005 Katrina and Rita hurricane disasters, the 2004 tsunami, and the 2001 attacks on the World Trade Center and Pentagon highlight the inadequacy of current mass casualty response systems. Effective disaster response to natural, unintentional,

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and intentional mass casualty incidents (e.g., "all hazards events") represents one of the greatest challenges to a country's emergency response infrastructure.

Nurses perform strategic research, administrative, and practice functions in emergency planning and mass casualty events (MCEs) (Stein, 2008). Nurses must plan for adequate staffing (Joint Commission on Accreditation of Healthcare Organizations [JCAHO], 2005), establish communication protocols, coordinate with the multiple agencies involved in MCEs, triage (Association of Perioperative Registered Nurses, 2007; JCAHO, 2005; Perry & Lindell, 2005), and track patients. Existing information systems are inadequate to support these functions (Ash, Berg, & Coiera, 2004; Birnbaum, 2002), and provide contradictory information (Jederberg, 2005).

Gaps exist in the generation and dissemination of disaster response research to healthcare professionals (Subbarao et al. 2008). There is little literature evaluating mass casualty response systems and no gold standard for measuring the effectiveness of information decision support data used in response to MCEs. Finally, further research is needed to build the underlying evidence base required to develop accurate quality measures and assessments (Ash et al., 2004). A necessary precursor to closing these gaps is the development of a comprehensive theoretically based conceptual model of mass casualty events. This study built a comprehensive model.

Background

Any number of natural, unintended, or deliberate catastrophic events may necessitate the effective, timely management of mass casualties (Fry & Lenert, 2005; Perrow, 2006; Simon & Teperman, 2001; Sundnes & Birnbaum, 2003). The casualties generated by such disasters can overwhelm existing healthcare facilities, jeopardizing the lives of victims and healthcare providers alike. The triage that occurs in a mass casualty event covers the entire continuum of care (Hoey & Schwab, 2004), including rescue from a potentially dangerous environment; decontamination if appropriate; ongoing prioritization of the sick and injured based on the severity of their conditions and chance for survival with appropriate healthcare intervention; rapid stabilization; and appropriate transport to a treatment facility. Incorrectly performed triage can underestimate the need of critically injured patients for immediate care, resulting in preventable deaths or deformities (undertriage) or overestimating the extent of minor injuries, resulting in mortality or disability of patients with more severe injuries (overtriage; Armstrong, Hammond, Hirshberg, & Frykberg, 2008; Frykberg, 2004; Hoey & Schwab; Parker, 2006; Sharma, 2005). The ability to treat patients that have the greatest chance for survival with healthcare intervention requires data for decision support that (a) characterizes patients accurately and efficiently (Frykberg, 2002, 2004; Hoey & Schwab) and (b) provides real-time visibility of data that tracks patients, personnel, resources, and potential hazards (Chan, Killeen, Griswold, & Lenert, 2004; Simon & Teperman).

Mass casualty triage is characterized by a multiagency organization in which multidisciplinary teams work together in a chaotic, highly dynamic technical environment. An MCE brings together a workforce with a wide skill mix of individuals from cross-jurisdictional agencies who may never have worked together before and who are often thrust into unfamiliar roles and tasks. The skill mix and characteristics of the workforce and their unfamiliarity with roles and tasks influence their ability to process data rapidly, which influences their efficiency and care outcomes (Chan et al., 2004; Gebbi & Merill, 2002). Successful triage depends on clear, accurate, complete, timely, and relevant data (Task Force on Quality Control of Disaster Management, 2009) and reliable decision support (JCAHO, 2005) to facilitate the concurrent analysis of nursing and workforce labor costs, workload, and staffing levels (Fernandes et al., 2005).

Significance

Because MCEs do not lend themselves to randomized controlled experiments, the science of disaster research is anecdotal and more descriptive than analytical (Birnbaum, 2002; Chan et al., 2004; Task Force on Quality Control of Disaster Management, 2009). No consensus currently exists on standardized definitions or indicators for specific aspects of disasters (Sundnes & Birnbaum, 2003). No theoretical framework exists to evaluate the effectiveness or efficacy of information systems for MCEs. Only one of the more than five systems currently used for mass casualty triage decision support has been tested under mass casualty conditions and validated by outcome data (Kahn, Schultz, Miller, & Anderson, 2008). None includes assessments of incidents involving chemical, radiological, or biological material, and none has been evaluated for use with the evolving information and communication technologies (Armstrong, Frykberg, & Burnis, 2008; Fernandes et al., 2005), an important gap in disaster research (Jenkins et al., 2008).

Real-time visibility of data that track patients, personnel, resources, and potential hazards is needed to improve situational awareness and provide decision support at each point along the continuum of care (Chan et al., 2004; Gebbi & Merill, 2002; Simon & Teperman, 2001). The 2001 Institute of Medicine report (Institute of Medicine, 2008) describes our current healthcare system as relatively untouched by the revolution in information technology and cites disaster care as a special area of concern. A theory-driven approach to MCEs would allow researchers to ask questions about the interactions between patients-victims, healthcare professionals, information technology, and information systems. A comprehensive theoretical model would facilitate the study of information needs throughout the triage continuum, including the effects of cognitive workload, environmental factors, and technology, as well as the impact of promising interventions (auf der Heide, 2006).

Mass Casualty Conceptual Model (MCCM)

The MCCM (Figure) was derived from empirical observations, insights, and deductions, existing literature, and theoretical-conceptual models. The conceptual model is contextually driven and multilevel with temporally ordered dynamic interactions. An open systems approach was used to study the effects of context on the functioning and information needs of multidisciplinary teams during mass casualty triage. Structural Contingency Theory (SCT), Technology Theory (TC), and Vicente's Human-Tech Ladder Model (Vicente, 2004) influenced development of the model and measurement variables for each construct.

SCT views context as both external (outside the boundaries of the focal unit of interest) and internal (within the focal unit of interest). TC emphasizes the internal context and focuses on information technology, structure and, triage. SCT (Burns & Stalker, 1961; Lawrence & Lorsch, 1967) measures the fit between structure and contingency factors, including (a) contextual factors such as the duration, setting, size and nature of the environment; (b) patients that affect differentiation and integration of the organization; and (c) structure or organizational framework needed by each triage unit to support the workforce in managing diverse patient needs. TC describes the processes, activities, and knowledge to transform materials and inputs into organizational outputs (Jaffee, 2001). Vicente's Model was included to study the fit of information technology to the workforce. Indicators include ergonomics, functionality, work flow patterns, rates, and amount.

The MCCM depicts five stages that impact the continuum of care during an MCE. Extant literature suggested the key constructs. Table 1 summarizes the 10 hypothesized constructs and relationships, and the 44 indicators, along with the theoretical base for each stage.

- Stage I (Contextual Environment): environmental factors that initiate and influence MCEs, patients affected, and resources available, including the following constructs: Organizational Customs, Triage Unit Organizational Complexity, Environmental Context, Patients, Resources, and Workforce.
- Stage II (Informational Environment): information and technology necessary to control and support an appropriate work flow design that matches the skill mix and experience of the available workforce. Stage II includes the Information Technology (IT) construct.
- Stage III (Structural Environment): ad hoc organizational structure used to organize a scalable multidisciplinary emergency response to incidents of any magnitude and includes the Structure construct. This stage describes the organizational framework needed by each triage unit (from hierarchical to flexible) to support the workforce in managing the diverse needs of each patient. The degree to which a hierarchical or flexible structure is appropriate is hypothesized to be influenced by the knowledge and technology available at the point of care to control patient variance at the source. IT directly influences the Structural Environment, and Structure influences IT, as illustrated by the bidirectional arrows in the Figure.
- Stage IV (Triage): the process used to classify and prioritize victims according to predetermined severity algorithms to ensure the greatest survivability with limited resources includes the Triage construct. Accurate triage depends on an appropriate organizational structure and IT to facilitate communication that assists the workforce to accurately prioritize the treatment of patients while controlling resources.
- Stage V (Goals): outcomes that include the numbers of lives saved and deformities prevented, the number of injuries prevented to both patients and the workforce, and the appropriate use of resources to measure the effectiveness of the organizational system.

The United States and other countries use the Incident Command Structure (ICS) management system to organize scalable emergency responses. Activating the ICS system creates an ad hoc organizational structure for a multidisciplinary (e.g., police, fire, rescue, medicine, nursing, and public health) workforce (www.training.fema.gov/EMIWeb/IS/is100.asp) that supports triage functions across the continuum of care. Within ICS, the primary goal of mass casualty triage is to identify the resources needed to adequately and efficiently treat the patients who have the greatest chance for survival. Given the goal of healthcare during MCE as increased survivability with minimal disability within a context of restricted resources, organizational systems must be able to respond quickly in ways that positively influence outcomes. The structure is unique because of its short, temporary life cycle, the unpredictability of the workforce, dynamic environmental conditions, and the diversity of patients. The work structure is, in turn, influenced by such factors as (a) organizational customs (the life cycle of the event and leadership style of management); (b) triage level organizational complexity (number of workforce specialties, size of the workforce, relationships within the functional unit of the workforce, and degree of technology used within the triage unit); (c) patients (individual characteristics); (d) resources (availability, type, and location); and (e) the characteristics of information and technology needed to support this entire process.

Methods

A modified Delphi process validated the proposed MCCM through the consensus of an expert panel. Computer, Internet, and email applications supported the modified Delphi process. An online custom survey software tool (www.surveymonkey.com) provided Internet capability to create and collect responses for each round of questions. The University of Arizona's Institutional Review Board Approved the research.

Sample

A purposeful sample of experts was recruited from emergency preparedness or response organizations across the United States. Candidates for panel membership completed a panel profile survey. Panel eligibility criteria included (a) a position title that reflected direct involvement in local, regional or county, state, federal, or military emergency preparedness, response, or research; (b) multiple provider and emergency planning, response, or research positions; (c) self-rating of expertise of 3 or higher on a 5-point Likert scale in which 5 indicated high expertise; and (d) availability of a computer with audio, Internet, and e-mail access.

Eighteen experts met all the selection criteria and were invited to participate. The sample included an equal number of males (n=9) and females (n=9), and the education level was similar for males and females, although males reported holding more credentials than females. The mean years employed in emergency preparedness (12.5) and mean rating of expertise (4.0) were higher for males than females. All seven position titles were represented. The majority of the panel (72%) represented the northeast geographical area. Given the limited pool of experts in this specialized field, this was deemed to be an adequate sample size (Akins, 2005; Linestone & Turoff, 2002).

Procedure

Panelists were sent customized e-mails through SurveyMonkey, including a hyperlink to the questionnaire when a round of questionnaires was available. Experts were asked to evaluate the proposed constructs and the relationships between each construct using a 7-point Likert scale (1=not important and 7=critically important to mass casualty triage). Experts were also asked to (a) identify and define any additional constructs or changes in relationship links needed to adequately assess the continuum of care during mass casualty triage; (b) whether each indicator for constructs should be retained, modified, or deleted and, if appropriate, how they would modify the indicator; and (c) to identify and define any additional indicators needed.

Data from each round were analyzed and the results sent to panelists within 2 days after the close of each Delphi round. Feedback included aggregated (de-identified) data in the form of central tendency, dispersion, and comment summaries, as well as the revised model modified based on results from the previous round. The revised model and panelists' responses from the first Delphi round formed the basis for the second round of questions.

The Delphi process continued until criteria for consensus or stability were met. Criteria for consensus were satisfied when (a) interquartile range in scores was no more than one scale point (Verran, 1981) for each construct or relationship or (b) interrater agreement was 70% or greater (Snyder-Halpern, 2001) for each indicator. Stability was calculated for items that did not satisfy the consensus criteria to indicate a stopping point for the process. Stability was satisfied when the change in the distribution of responses was less than 15% from one round to the next (Schiebe, Skutashc, & Schofer, 2002). The mean response for each question was used to calculate the change in distribution from one round to the next. During the second Delphi round, experts were asked to rate the model's usefulness using a 7-point Likert scale (1=*not useful* and 7=*very useful* to the further study of information and technology requirements during MCEs).

Results

Two rounds of the Delphi process were needed to satisfy the criteria for consensus or stability. Sixteen of the original 18 expert panel members (89%) responded to Round 1 of the Delphi process. Thirteen (81%) of the 16 completed Round 2. The panel reached consensus and/or sufficient stability to retain all 10 constructs, 9 relationships, and 39 of 44 indicators (Table 2). [Correction added after online publication November 19, 2009: "Table 1" has been updated as "Table 2".] Changes to the model were based on individual comments that were subsequently supported by other panelists and/or by current literature or model underpinnings.

The first research question addressed the appropriateness of each model construct. Stability statistics indicated movement in opinion among the experts between rounds in the areas of Triage Unit Organizational Complexity (−6% change), Patients (8% change), Workforce (8% change), and Information Technology (6% change). However, all fell within the acceptable range for stability and were retained. The second research question addressed the appropriateness of the proposed relations among the constructs. All nine relationships satisfied the criteria for either consensus and/or stability and were retained. The third research question addressed the appropriateness of each indicator as a measurement for the constructs. Table 3 lists constructs and indicators. [Correction added after online publication November 19, 2009: "Table 1" has been updated as "Table 3".] Several indicators were added or modified or eliminated in the following constructs:

- Organizational Customs: The incentive structure indicator was deleted and disaster planning added to reflect JCAHO (2006) standards and compliance with Hospital Emergency Incident Command Systems (www.heics.com/download.htm).
- Triage Level Organizational Complexity: Drills were added to reflect JCAHO (2006) standards.
- Environmental Context: Indicators were modified to reflect Perrow's (2006) more inclusive terminology of natural, unintended, and deliberate disasters. The indicators urban and rural were replaced with proximity to the disaster. Distance to health facilities and competing disasters were added.
- Resources: The amount indicator was changed to availability.
- Workforce: The age indicator was changed to physical health, and willingness to work was added based on the work of Rosenfeld, Raffle, Brickner, Henry, and Rosati (2007).
- Outcomes: Safety was added based on research by Landrigan et al. (2004) and Macintyre et al. (2000).

Tables 2 and 3 summarize the results of Delphi Rounds 1 and 2. During the second round, experts were asked to evaluate the model's usefulness for further study of information and technology requirements. Sixty-seven percent of the experts rated the models useful as 5 or greater on the 7-point Likert scale (mean of 5.3).

Discussion

The findings presented here are preliminary and exploratory. Experts agreed that model constructs and relationships were valid representations of mass casualty triage. Indicators of the constructs were modified based on experts' responses and comments. The research utilized a purposeful sample of 18 experts known to the researcher or recommended by panel members. However, the diversity of the panel members and representation at all levels of emergency preparedness are strengths of the study. Still, the lack of randomization prevents the generalization of these findings to all hazards events.

Multilevel modeling methods allow researchers to examine simultaneously the effect of individual-level and group-level predictors on outcomes (Cho, 2003). Additional research is needed to evaluate the effectiveness of online processes. Research that evaluates functionality and ease of access for online resources would provide additional insights into the use of this modality for future studies. The scope of the MCCM is limited to the acute care triage continuum of care. Future research is needed to extend the model beyond the acute care phase to measure longer term morbidity and mortality.

Conclusions

The MCCM is a first step toward understanding the context in which MCEs take place and the variables that influence outcomes. Mass casualty triage involves a multiagency organization where multidisciplinary teams work in a chaotic, dynamic sociotechnical environment. Success depends on clear, accurate, and fast communication and information systems. Nurses and health professionals in all practice settings should be part of the planning and training for emergencies (American Nurses Association, 2008), as well as the discovery of new knowledge and frameworks that provide the best evidence for MCE care. The MCCM may provide an impetus to the needed discovery.

Clinical Resources

- Department of Homeland Security Federal Emergency Management Agency. Retrieved May 22, 2009, from http://www.training.fema.gov/EMIWeb/IS/is100.asp
- Task Force on Quality Control of Disaster Management. (2009). Health disaster management: Guidelines for evaluation and research in the Utstein style: Executive summary. Retrieved April 17, 2009, from http://pdm.medicine.wisc.edu/sundnes.htm

References

Akins RB, Tolson H, Cole BR. Stability of response characteristics of a Delphi panel: Application of bootstrap data expansion. BMC Medical Research Methodology. 2005; 5:37. from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1318466. [PubMed: 16321161]

American Nurses Association. [Retrieved July 20, 2009] Adapting standards of care under extreme conditions: Guidance for professionals during disasters, pandemics, and other extreme emergencies. 2008. from http://nursingworld.org/

Armstrong J, Frykberg E, Burnis D. Toward a national standard in primary mass casualty triage. Disaster Medicine and Public Health Preparedness. 2008; 2(1):S8. [PubMed: 18769269]

Armstrong J, Hammond J, Hirshberg A, Frykberg E. Is overtriage associated with increased mortality? The evidence says "yes.". Disaster Medicine and Public Health Preparedness. 2008; 2:S8–S10. [PubMed: 18769269]

Ash J, Berg M, Coiera E. Some unintended consequences of information technology in health care: The nature of patient care-information system-related errors. Journal of the American Medical Informatics Association. 2004; 11(2):104–112. [PubMed: 14633936]

Association of Perioperative Registered Nurses. AORN guidance statement: Mass casualty, triage, and evacuation. AORN Journal. 2007; 85(4):792, 794–795, 797–800. [PubMed: 17458024]

Auf der Heide E. The importance of evidence-based disaster planning. Annals of Emergency Medicine. 2006; 47(1):34–49. [PubMed: 16387217]

Birnbaum M. Disaster medicine: Status, roles, responsibilities, and needs. Prehospital and Disaster Medicine. 2002; 17(3):117–118. [PubMed: 12627913]

Burns, T.; Stalker, GM. The management of innovation. London: Tavistock; 1961.

Chan T, Killeen J, Griswold W, Lenert L. Information technology and emergency medical care during disasters. Academic Emergency Medicine. 2004; 11(11):1229–1236. [PubMed: 15528589]

Cho SH. Using multilevel analysis in patient and organizational outcomes research. Nursing Research. 2003; 52(1):61–65. [PubMed: 12552178]

Fernandes C, Tanabe P, Gilboy N, Johnson L, McNair R, Alexander M, et al. Five-level triage: A report from the ACEP/ENA five-level triage task force. Journal of Emergency Nursing. 2005; 31(1):39–50. [PubMed: 15682128]

Fry, E.; Lenert, L. MASCAL: RFID tracking of patients, staff and equipment to enhance hospital response to mass casualty events. In: Ash, J.; Tarczy-Hornoch, P., editors. American medical informatics association annual symposium proceeding; American Medical Informatics Association; Washington, DC. 2005. p. 261-265.

Frykberg E. Medical management of disaster and mass casualties from terrorist bombings: How can we cope? Journal of Trauma. 2002; 53(2):201–212. [PubMed: 12169923]

Frykberg E. Principles of mass casualty management following terrorist disasters. Annals of Surgery. 2004; 239(3):319–321. [PubMed: 15075647]

Gebbi K, Merill J. Public health worker competencies for emergency response. Journal of Public Health Management Practice. 2002; 8(3):73–81. [PubMed: 15156628]

Hoey G, Schwab C. Level I center triage and mass casualties. Clinical Orthopedics and Related Research. 2004; 422:23–29.

Institute of Medicine. Washington, DC: National Academy of Sciences; 2008. Crossing the quality chasm: A new health system for the 21st century. Released March 1, 2001, updated May 16, 2005, cited September 25, 2008. from http://www.iom.edu/?id=12736 [Retrieved July 23, 2009]

Jaffee, D. Organization theory: Tension and change. New York: McGraw-Hill; 2001.

Jederberg W. Issues with the integration of technical information in planning for the responding to nontraditional disasters. Journal of Toxicology and Environmental Health Part A. 2005; 68(11–12):877–888. [PubMed: 16020182]

Jenkins J, McCarthy M, Sauer L, Green G, Staurt S, Thomas T, et al. Mass-casualty triage: Time for an evidence-based approach. Prehospital Disaster Medicine. 2008; 23(1):3–8. [PubMed: 18491654]

Joint Commission on Accreditation of Healthcare Organizations. [Retrieved July 20, 2009] Standing together: An emergency planning guide for America's communities. 2005. from http://www.jointcommission.org/NR/rdonlyres/FE29E7D3-22AA-4DEB-94B2-5E8D507F92D1/0/planning_guide.pdf

Joint Commission on Accreditation of Healthcare Organizations. [Retrieved July 20, 2009] Hospital accreditation standards for emergency management planning emergency management drills infection control disaster privileges. 2006. from http://www.efilmgroup.com/efg/blurbimage/JCAHOStdforEmergency.pdf

Kahn C, Schultz C, Miller K, Anderson C. Does START triage work? An outcomes level assessment of use at a mass casualty event. Academic Emergency Medicine. 2009; 53(3):424–430.

Landrigan P, Lioy P, Thurston G, Berkowitz G, Chen L, Chillrud S, et al. Health and environmental consequences of the world trade center disaster. Environmental Health Perspectives. 2004; 112(6):731–739. [PubMed: 15121517]

Lawrence, P.; Lorsch, J. Organization and environment: Managing differentiation and integration. Homewood, IL: Richard D. Irwin; 1967.

Linestone, HA.; Turoff, M., editors. [Retrieved March 6, 2007] The Delphi method: Techniques and applications. 2002. from http://www.is.njit.edu/pubs/delphibook/delphibook.pdf

Macintyre A, Christopher G, Eitzen E, Gum R, Weir S, DeAtley C, et al. Weapons of mass destruction events with contaminated casualties. Journal of the American Medical Association. 2000; 283(2):242–249. [PubMed: 10634341]

Parker M. Critical care and disaster management. Critical Care Medicine. 2006; 34(Suppl. 3):S52–S55. [PubMed: 16477203]

Perrow, C. Disasters ever more? Reducing U.S. vulnerabilities. In: Rodriguez, H.; Quaranteli, E.; Dynes, RR., editors. Handbook of disaster research. Berlin: Springer-Verlag; 2006. p. 521-533.

Perry R, Lindell M. Hospital planning for weapons of mass destruction incidents [Symposium]. Journal of Postgraduate Medicine. 2005; 52:116–120. [PubMed: 16679675]

Rosenfeld, P.; Raffle, S.; Brickner, C.; Henry, M.; Rosati, R. Ability and willingness to report to work during a disaster: Results of a survey of home health care employees; Paper presented at the 135th Annual Meeting and Exposition of the American Public Health Association on Public Health Management of Disasters; Washington, DC. 2007 Nov.

Schiebe, M.; Skutashc, M.; Schofer, J. Linestone, HA.; Turoff, M., editors. [Retrieved March 6, 2007] Experiments in Delphi methodology. The Delphi method: Techniques and applications. 2002. from http://www.is.njit.edu/pubs/delphibook/delphibook.pdf

Sharma R. Development of pre-hospital trauma-care-system—An overview. Injury. 2005; 36(5):579–587. [PubMed: 15826614]

Simon R, Teperman S. The world trade center attack: Lessons for disaster management. Critical Care. 2001; 5:318–320. [PubMed: 11737917]

Snyder-Halpern R. Indicators of organizational readiness for clinical information technology/systems innovation: A Delphi study. International Journal of Medical Informatics. 2001; 63(3):179–204. [PubMed: 11502432]

Stein L. Mass casualty triage. Oklahoma Nurse. 2008 from http://findarticles.com/p/articles/mi_6853/is_2_53/ai_n28528030.

Subbarao I, Lyznicki M, Hsu E, Gebbi K, Markenson D, Barzansky B, et al. A consensus-based educational framework and competency set for the discipline of disaster medicine and public health. Disaster Medicine and Public Health Preparedness. 2008; 2(1):57–68. [PubMed: 18388659]

Sundnes K, Birnbaum M. Guidelines for evaluation and research in the Utstein style. Journal of Pre-Hospital and Disaster Medicine. 2003; 17(Suppl. 3):1–177.

Task Force on Quality Control of Disaster Management. [Retrieved April 17, 2009] Health disaster management: Guidelines for evaluation and research in the Utstein style: Executive summary. 2009. from http://pdm.medicine.wisc.edu/sundnes.htm

Verran J. Delineation of ambulatory care nursing practice. Journal of Ambulatory Care Management. 1981; 4(2):1–13. [PubMed: 10298168]

Vicente, K. The human factor. New York: Routhledge; 2004.

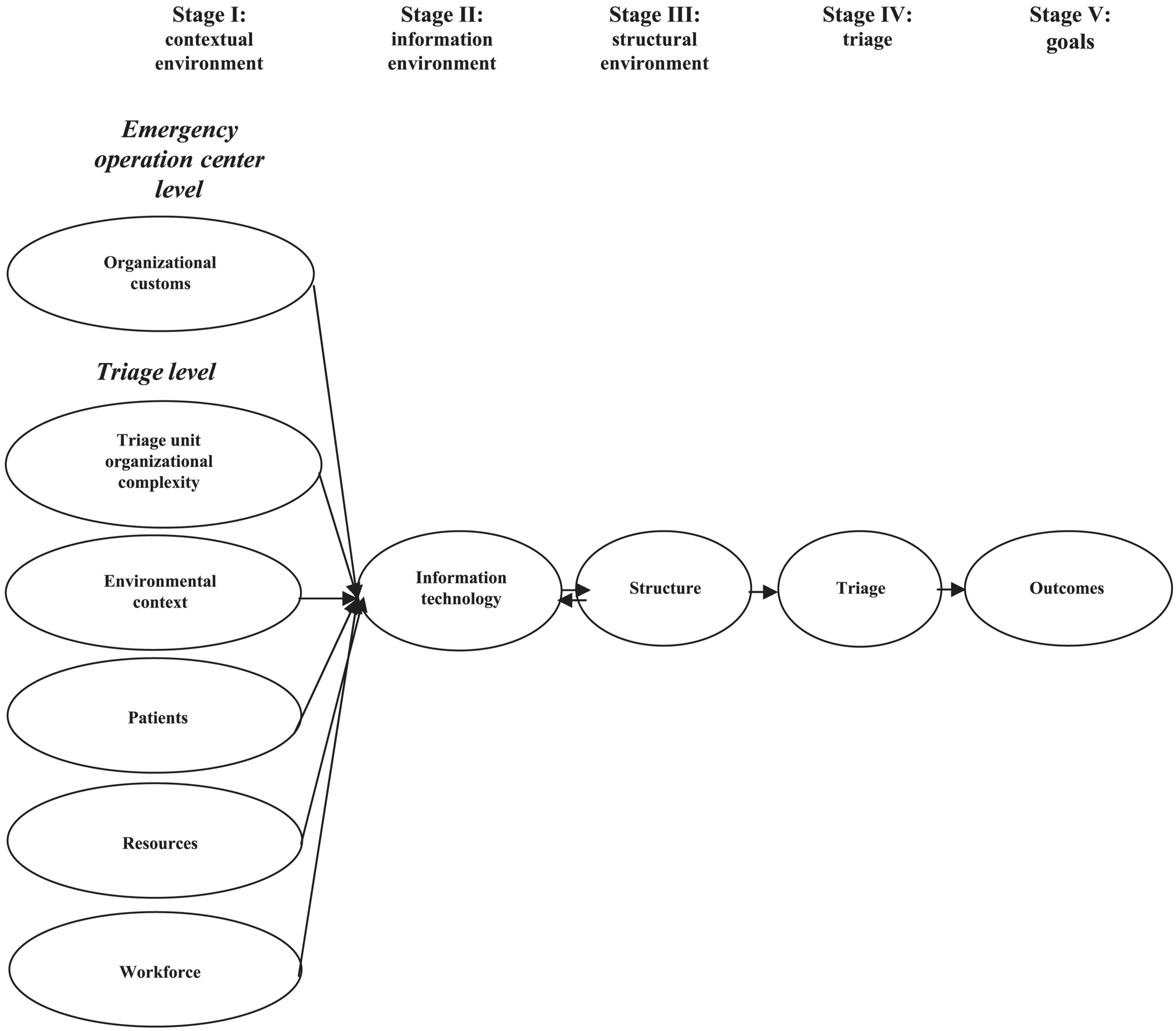

Figure.
Mass Casualty Conceptual Model (MCCM)©.

Table 1

MCCM Stages, Theory/Model Influences, Constructs, and Indicators

Stage I Contextual ENV	**Stage II Information ENV**	**Stage III Structural ENV**	**Stage IV Triage**	**Stage V Goals**
Influenced by Structural Contingency Theory and Technology Theory	Influenced by Structural Contingency Theory, Technology Theory, and Vicente's Model	Influenced by Structural Contingency Theory and Technology Theory	Influenced by Structural Contingency Theory and Technology Theory	Influenced by Structural Contingency Theory, Technology Theory, and Vicente's Model
Organizational customs Shared beliefs Life cycle Growth Stability Leadership style (Disaster planning) Triage level organizational complexity Size Number of specialties Technology readiness High tech Team culture Self-regulation Relationships (Exercises/drills) Environmental context (Competing disasters) Nature of disaster <Natural> <Unintended> <Deliberate> [Manmade] [Natural] Geographical size Duration Warning systems <Setting> (Distance to healthcare facilities) (Proximity to disaster) Patients Injury characteristics Demographics Variability Resources Categories (Availability) [Amount] Locations Workforce Credentials/licenses Experience Experience with technology Training Skill mix (Cross training) (Competency) Education (Willingness to work) (Physical health) [Age]	Information technology Technology hard/soft Characteristics (Access to power) (Redundancy) Functionality Amount (Connectivity) (Access) (Currency) Work flow Rate of flow Information technology Information Terminology Flow Security Characteristics	Structure Work flow variability Changes in patient Triage classification Search behaviors Knowledge Experience Intuition Structure Hierarchical to flexible	Triage Time to triage Classification Prioritization	Outcomes Patient outcomes Survival Disabled Resources Overtriage Undertriage (Safety) (Patient injuries) (Workforce injuries)

( ), indicators added; [ ], indictors deleted, <>, indicators modified.

Table 2

Results from Delphi Rounds 1 and 2

	Round 1		Round 2		
Constructs	Mean	Interquartile range	Mean	Interquartile range	Stability round 1–2 (%)
Organizational customs	4.9	3.0–6.3	5.0[a]	4.0–6.0	1.2
Triage unit organizational complexity	5.8	5.0–7.0	5.5[b]	5.0–6.0	−6.0
Environmental context	5.9	5.0–7.0	5.9[a]	5.0–7.0	−0.3
Patients	5.6	5.0–6.5	6.0[b]	6.0–7.0	7.9
Resources	5.9[c]	5.8–6.3	—	—	—
Workforce	5.6	5.0–6.3	6.1[b]	6.0–7.0	7.9
Information technology	4.5	3.5–6.0	4.8[a]	4.0–6.0	6.0
Structure	5.3	4.8–6.0	5.0[a]	4.0–6.0	−4.8
Triage	5.9	5.8–7.0	6.5[b]	6.0–7.0	3.6
Outcomes	5.6	4.5–7.0	5.5[a]	5.0–6.5	−2.6
Relationships					
Influence of organizational customs on information technology	4.4	2.8–6.0	4.0[a]	3.0–5.0	−9.9
Influence of triage unit organizational complexity on information technology	4.4	3.0–5.3	4.2[a]	3.0–5.0	−3.4
Influence of environmental context on information technology	4.9	4.0–6.0	4.6[a]	3.0–6.0	−6.6
Influence of patients on information technology	4.7	4.0–6.0	4.8[a]	3.0–6.3	1.3
Influence of resources on information technology	5.0	4.0–6.0	5.5[b]	5.0–6.0	10.0
Influence of workforce on information technology	5.4	4.0–6.5	5.9[b]	5.0–6.0	−1.0
Influence of information technology on structure	4.9	4.0–6.0	4.8[a]	4.5–6.0	−1.0
Influence of structure on triage	5.2	4.8–6.0	5.3[a]	4.0–6.3	2.8
Influence of triage on outcomes	5.9	5.8–7.0	6.1[b]	6.0–7.0	2.3

[a]Retained based on stability (change in the distribution of responses less than 15% from Round 1 to Round 2).

[b]Retained based on both consensus and stability (criteria for consensus and stability met).

[c]Retained based on consensus (interquartile range no more than one scale point).

Table 3

Percent Agreement and Stability from Delphi Rounds 1 and 2

	Round 1			Round 2			
Construct indicators	**Delete**	**Modify**	**Retain**	**Delete**	**Modify**	**Retain**	**Stability round 1–2**
Organizational customs							
Shared beliefs	38	6	56	31	7	62[a]	5.5
Life cycle	19	31	50	15	39[a]	46	−0.2
Incentive structure	31	6	63	46[a]	8	46	−13.5
Leadership style	7	14	79[b]	—	—	—	—
Triage level organizational complexity							
Number of specialties	13	20	67	18	18	64[c]	−3.1
Size	14	14	72[b]	—	—	—	—
High tech	21	36	43	20	60[a]	20	−9.7
Team culture	0	14	86[b]	—	—	—	—
Environmental context							
Nature of Disaster	6	19	75	—	—	—	—
Geographical Size	0	13	87	—	—	—	—
Warning Systems	13	13	74	—	—	—	—
Duration	0	13	87	—	—	—	—
Setting	19	25	56	23	15	62	0.4
Resources							
Categories	0	27	73[b]	—	—	—	—
Availability	0	33	67	0	0	100[c]	12.5
Location	7	20	73[b]	—	—	—	—
Workforce							
Credentials/licenses	12	25	63	0	8	92[b]	16.7
Experience	6	6	88[b]	—	—	—	—
Experience with technology	13	31	56	8	17	75[c]	9.4

Construct indicators	Round 1			Round 2			
	Delete	Modify	Retain	Delete	Modify	Retain	Stability round 1–2
Training	0	12	88[b]	—	—	—	—
Skill mix	19	25	56	8	33	59[a]	5.3
Education	12	25	63	8	25	67[a]	3.3
Safety/health needs	0	31	69	17	17	66[a]	−7.0
Age	47	47	6	70[c]	15	15	−8.7
Information technology (Technology)							
Characteristics	20	33	47	22	39[a]	39	−5.0
Work flow	13	20	67	8	23	69[c]	3.3
Rate of flow	13	20	67	8	15	77[c]	6.3
Information technology (Information)							
Terminology	0	31	69	17	17	66[a]	−7.0
Flow	0	13	87[b]	—	—	—	—
Security	12	25	63	23	23	54[a]	−7.7
Characteristics	14	21	65	8	0	92[c]	13.9
Structure							
Work flow variability	0	19	81[b]	—	—	—	—
Search behaviors	0	25	75[b]	—	—	—	—
Structure	7	33	60	0	31	69[c]	6.3
Triage							
Time to triage	0	19	81[b]	—	—	—	—
Classification	0	19	81[b]	—	—	—	—
Prioritization	0	12	88[b]	—	—	—	—
Outcomes (Patients)							
Survivability	—	—	—	11	0	89[b]	—
Disability	—	—	—	11	0	89[b]	—
Outcomes (Resources)							

Construct indicators	Round 1			Round 2			
	Delete	Modify	Retain	Delete	Modify	Retain	Stability round 1–2
Overtriage	13	20	67	8	8	84[c]	8.6

[a]Retained based on stability (change in the distribution of responses less than 15% from Round 1 to Round 2).

[b]Decision based on consensus (interrater agreement level of 70% or greater).

[c]Retained based on both consensus and stability (criteria for consensus and stability met). [Correction added after online publication November 19, 2009: Table 3 section “Environmental Context” has been updated from the original version, with different data.]