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Disaster relief supply chain quality management (DRSCQM)

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Abstract

Purpose – The purpose of this paper is to develop a framework for disaster relief supply chain quality management (DRSCQM).

Design/methodology/approach – This paper introduces a structured approach to making decisions in the following areas: system foundation, system constraints, initial sudden natural disaster encounter point(s), the intensity of disaster, the efficacy of the disaster relief supply chain systems, and post-disaster relief management.

Findings – The context-intervention-mechanism-outcome logic provides guidelines for facilitating Lean Six Sigma to eliminate wastes and improve the overall performance of the DRSCQM.

Research limitations/implications – The theoretical frameworks will enhance the current knowledge base in DRSCQM literature and will also be helpful to manage disaster relief operations and supply chains. However, there is a need to conduct empirical studies based on the proposed frameworks in the future.

Practical implications – A transformation process based on Dr Deming's plan-do-check-act cycle has also been proposed to show how a relief organization can assess its current maturity level, react to it, develop more sustainable disaster relief practices, and move the entire system in the right direction.

Social implications – The systemic and holistic procedure developed in this paper views the environment of disaster relief as dynamic, complex, chaotic, and ever-changing and takes into account the fact that relief organizations' actions often involve a team of diverse specialists working on a project basis.

Originality/value – The framework presented here helps to improve the efficiency and the effectiveness of disaster relief supply chain management. This is timely and important now as there continues to be an increase in climate-related natural disasters.

Keywords Lean Six Sigma, Supply chain quality management, Disaster relief, Quality management principles

Paper type Research paper

1. Introduction

The Earth is increasingly witnessing natural disasters (Duran *et al.*, 2013; Cozzolino, 2012; Schwester, 2012; Balcik *et al.*, 2010; Altay and Green, 2006; Thomas

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and Kopczak, 2005). Earthquake measuring 6.1, for example hit Haiti in 2010. Hurricane Sandy hit New York City and New Jersey in 2012. Landslides hit the Washington state town of Oso in 2014. A strong earthquake hit the Chinese province of Sichuan in 2013. Nigeria faced massive flooding in 2012, and in 2013, it faced new challenges as a result of massive flooding from heavy rain falls. When natural disasters occur, policy makers and stakeholders are challenged to make quick and tough decisions with limited resources and information. It is important in these situations to be able to provide quality services responsibly and timely to disaster victims. The ability to deliver these services timely and professionally presents serious challenges. Thomas and Kopczak (2005), for example, identify five core challenges in the context of disaster relief operations:

- lack of recognition of the importance of logistics;
- lack of professional staff;
- inadequate use of technology;
- lack of institutional learning; and
- limited collaboration.

These challenges may be addressed through supply chain management (SCM). The aim of SCM is to follow a structured approach to making decisions. Emphases are placed on order procurement and fulfilment as well as performance issues relating to the processes along the supply chain. Disaster relief execution begins with a good understanding of the unique attributes of disaster relief supply chain management (DRSCM). In Table I, a systemic view of DRSCM is presented and it is contrasted with the traditional SCM. Stakeholders are better able to deal with the challenges they face when they understand the unique attributes of DRSCM.

This paper explores the role of quality management models especially Lean Six Sigma (LSS) in facilitating planning, implementing, reviewing, and improving a DRSCM system. A LSS-driven disaster relief SCM system is referred to as the disaster relief supply chain quality management (DRSCQM) system in this study.

The rest of the paper is organized as follows. In the next section, we present a unified DRSCQM focussing on three components: physical disaster relief supply chain systems, the disaster relief life cycle, and the context-intervention-mechanism-outcome (CIMO) logic (see Figure 1). In section three, we apply LSS to this concept (i.e. DRSCQM). Five principles of LSS are identified. In section four, we discuss implementation issues. In section five, the practical guidelines and implications of DRSCQM transformation are discussed. Finally, conclusions are presented.

2. The birth of DRSCQM system

DRSCM system is used for the purposes of structuring, bundling, and leveraging resources to respond to humanitarian needs in the event of major natural disaster. DRSCM may be linked to quality management tools and concepts such as LSS and referred to as the DRSCQM.

As shown in Figure 1, DRSCM consists of three components: physical disaster relief supply chain systems, the disaster relief life cycle, and the CIMO logic.

The focus of the physical system is to link every stakeholder in disaster relief operations. As shown in Figure 1, information flows laterally between the stakeholders. Relief supply chain is difficult to manage due to the high degree of

Attributes	Traditional SCM	DRSCM
What does this function do?	Dealing with issues related to the supply network structure, routing activities, and measurement	Managing to collaborate to achieve a disaster relief vision, create unique projects with values, align process objectives across all of the units in the disaster relief supply chain, and meet stakeholders' needs along the disaster relief life cycle
Who is involved?	A team of employees dealing with repetitive daily activities	A team of diverse specialists working on a project basis
How should functions be linked?	Through the use of Porter's value chain to link customer order, replenishment, manufacturing, and procurement	Through the use of project (i.e. disaster relief) life cycle concepts to link mitigation, preparation, response, and recovery
What challenges does the function face?	Using existing supply chain systems, properties, and capabilities	Dealing with uncertain demand and supplies (e.g. voluntary contributions), limited resources, limited communication capacities
What are high-performance drivers?	Continually evolving in two main areas: customer orientation and operations orientation	Continually evolving in two main areas: quality science and process management
What is the key attribute?	Keeping the momentum going; dealing with ongoing buy or make decisions	Attempting to deliver quality of care within a short-time frame in a very unstable environment (e.g. infrastructure is damaged and degraded); involving NGOs and military

Table I.
A contrast of traditional supply chain management (SCM) to disaster relief supply chain management (DRSCM) – the "5W + 1H" model

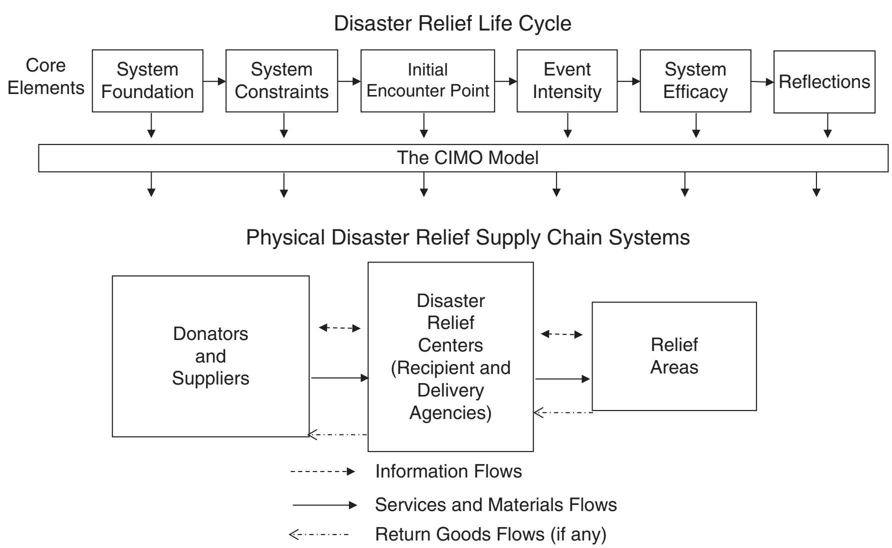


Figure 1.
Disaster relief supply chain quality management (DRSCQM) system

uncertainty with supplies and the complexity in coordinating a network of participants that are conveniently put together. Yet, these stakeholders need to work together as a team to be able to manage the disaster and deliver quality relief services to the communities in the disaster zones. When disasters do occur, response time is very important in providing relief and it is crucial in many cases in saving lives.

Cozzolino (2012) and Altay and Green (2006) note that stakeholders in disaster relief operations should pay particular attention to four phases of disaster relief life cycle: mitigation, preparedness, response, and reconstruction. Mitigation and preparedness are referred to as the "silent network." The objective is to do right things better, cheaper, and faster. The aim is to be prepared and also to mitigate against the occurrence of such disasters. However, when the disaster occurs, emphasis is shifted to responding to humanitarian needs. Here, the goal is on doing right things faster and better. Subsequently, reconstruction efforts are employed for the long term. Duran *et al.* (2013) suggest three core stages of disaster relief management: pre-disaster relief, disaster relief, and post-disaster relief. A well-designed disaster relief process should involve the following key activities: assessing relief needs, preparing for emergency rescue situations, activating operation centers and rescue teams, mobilizing relief items (from food/water to housing), and planning for the last mile transportation (Duran *et al.*, 2013, p. 450). If we explore disaster relief process from both the time value (doing right things faster) and the quality value (doing something better), we observe multiple integration points between the stakeholders in Figure 1. It is therefore essential that there are collective and collaborative efforts between the stakeholders in order to improve the response time and the quality of service that is delivered to the victims of disaster.

There are six potential areas that would need the collaboration and cooperation of all the stakeholders. These are: system foundations, system constraints, initial sudden natural disaster encounter point(s), the intensity of disaster, the efficacy of the disaster relief supply chain systems, and reflections and ongoing issues. These six areas constitute the disaster relief life cycle in the DRSCQM. They are critical to achieving the disaster relief goals set by stakeholders before, during, and after the disaster. They could also help in creating unique long- and short-term projects with a right set of values (e.g. time, quality, or cost), aligning process objectives across all of the units in the disaster relief supply chain, and meeting stakeholders' needs along the disaster relief life cycle. The ultimate aim of such a supply chain quality system is stakeholder satisfaction in the field of civil protection in the event of natural disaster.

The goals of the disaster relief as articulated by the policy makers should be known to all stakeholders. In this work, we use a strategic cycle known as the CIMO logic to better understand the disaster relief effort (Denyer and Tranfield, 2009). For the purpose of this paper, four major parts of this strategic cycle are briefly described as follows:

- context: aim, function, appearance, and interacting components (may be analyzed in the following four settings: institutional, supply chain, social, and natural);
- interventions: quality-driven interventions (may be analyzed from the following four perspectives: managerial, technical, structural, and behavioral);
- mechanism: DMAIC (define-measure-analyze-improve-control) and/or DMADV (define-measure-analyze-design-verify); and
- relevant outputs and outcomes.

The framework for the birth of DRSCQM system that is presented here ensures that LSS quality conscious systems are designed and developed. It enables disaster relief centers to customize their services and supply chains based on quality-driven principles and tools to meet the unique needs of their stakeholders in the event of major natural disaster.

3. Understanding LSS process improvement principles

Maleyeff (2007) points out that LSS is an important component of organizational success. It is a rigorous process management approach that aims at eliminating wastes while simultaneously achieving common goals set by the Six Sigma metrics (Madu, 2006). It relies on efficiency in all processes and the streamlining of activities across the organization. LSS focusses on achieving customer satisfaction through continuous improvement of processes by eliminating wastes and redundant activities (Locher, 2007; Madu, 2006; Assarlind *et al.*, 2012; Antony *et al.*, 2012). Consequently, risk is minimized and process variations and errors are reduced. It is a strategy for both repetitive and innovative processes. The application of LSS covers the entire value delivery chain. It helps organizations to become agile and to respond rapidly to their dynamic environments (Madu, 2006, p. 79; Antony *et al.*, 2012).

There are five guiding principles to LSS practice (see Table II). These are:

- planning for lean and quality;
- adopting creative problem-solving and risk assessment approaches;
- exploring computational opportunities;
- enabling conditions for lean and quality; and
- achieving greater communication and endorsement.

Processes can be improved by reducing complexity in the operations flow; making things better, faster, and cheaper; improving modeling and fault-finding accuracy; and taking purposeful actions. The adoption of LSS principles may potentially reduce the workload, risks, and development time of a disaster relief life cycle. This would subsequently improve the overall quality of the disaster relief supply chain process or projects. This is illustrated further below.

3.1 Planning for lean and quality

The ability to achieve quality outcomes under adverse conditions is an expectation of the natural disaster response. This is achieved through the application of a rigorous LSS process management in disaster relief life cycle. A LSS system has four simple "Final" causes: safety and environment, quality, delivery, and economy (Assarlind *et al.*, 2012). Plans need to be designed to contribute to the fullest realization of these goals. There are key challenges that are unique to disaster relief management. These challenges include (Psychogios *et al.*, 2012) lack of awareness, lack of strategic orientation, employee work culture, and habits. Each of these activities needs to be thoroughly planned and coordinated to enhance disaster relief management in the twenty-first century. This requires a structured design of the flow of materials, people, and processes.

3.2 Adopting creative problem-solving and risk assessment approaches

Schroeder *et al.* (2008, p. 545) note that it is important to "help employees understand and solve problems that cut across functional domain." LSS black belts may therefore be used to evaluate the root causes of wastes and process variability. They may also serve as project managers and lead cross-functional teams. The teams identify potential problems and conflicts that may make it difficult to achieve LSS and then

Table II. Lean Six Sigma principles – seeking the next level of operational excellence

Contributions	Author(s)	Main points
Planning for lean and quality	Lewis (2000)	"Being 'lean' can curtail the firm's ability to achieve long-term flexibility (p. 959)." The core of lean centers on flow, value, pull, perfection, and empowerment
	Carreira (2005)	Lean is a concept based on a system-wide vision, value-stream analyses, small improvements every day, and metrics defined by customers; It is not a home run once in a while approach
	Schroeder *et al.* (2008)	Six Sigma is "a structure that has both a controlling and exploring effect (p. 544)" This can be done through the use of improvement specialists, a structured method, and performance metrics
	Assarlind *et al.* (2012)	"There is an ongoing trend of integrating Lean and Six Sigma by adding Six Sigma projects to a Lean initiative (p. 23)"; Priorities include safety and environment, quality, delivery, and economy
	Psychogios *et al.* (2012)	Lean Six Sigma inhibitors include: lack of awareness for the need of Lean Six Sigma, lack of strategic orientation, and employee working mentality and habits
Adopting creative problem-solving and risk assessment approaches	Hammer (2002)	"Before beginning a six-sigma project, a company should create a SIPOC (supplier, input, process, output, customer) model of its processes, [...], and map that process." (p. 31)
	Locher (2007)	Lean thinking and Six Sigma can come together when redesigning business processes and addressing root causes in highly uncertain market environments
	Schroeder *et al.* (2008)	Structural exploration helps process improvement teams be open to and flexible regarding to new and different perspectives
	Assarlind *et al.* (2012)	The emphasis of Lean and Six Sigma is on the structural problem approach with tools such as value stream mapping and statistical models
Exploring computational opportunities	Breyfogle (1999)	Six Sigma is a concept involving the use of statistical tools and repeated, disciplined applications of the performance-improvement strategy on projects
	Locher (2007)	The various Lean Six Sigma tools can effectively address the root causes for the process variability due to work interruptions, multitasking, unpredictable demand, and the complexity of information
	Manville *et al.* (2012)	From middle managers' point of view, critical success factors include project selection and prioritization and training and education
	Manville *et al.* (2012)	"A greater role should be given to middle management in performance improvement and strategy formulation (p. 7)"

(*continued*)

Table II.

Contributions	Author(s)	Main points
Enabling conditions for lean and quality	Breyfogle (1999)	Six Sigma is designed "to change the culture through breakthrough improvement by focusing on out-of-the-box thinking in order to achieve aggressive, stretch goals." (p. 5)
	Hammer (2002)	Breakthrough improvements in performance require fundamental change; DMAIC is "not a vehicle for business transformation" (p. 31)
	Madu (2004)	There is high focus on empowerment, flexibility, quality, and productivity improvements
	Schroeder *et al.* (2008)	Higher levels of structural control with a special focus on outcome, behavioral, and social dimensions tend to result in higher organizational performance
	Schroeder *et al.* (2008)	A well-balanced system embodies four essential elements: leadership engagement, improvement specialists, strategic project selection, and structured method
Achieving greater communication and endorsement	Locher (2007)	The quality of the information is a foundation of Lean Six Sigma thinking; The concepts such as value streams and service families, when properly applied, can effect process change and maximize flow performance
	Schroeder *et al.* (2008)	Higher levels of structural exploration through the use of common language, multifunctional teams, and heavyweight project managers tend to result in higher organizational performance
	Antony *et al.* (2012)	Three metrics of communication and information management are identified: completeness, correctness, and timeliness; For the case of inaccurate data and information, four causes need to be examined: data, people, measurements, and communication methods
	Manville *et al.* (2012)	From middle managers' point of view, critical success factors include senior management commitment, and linking Lean Six Sigma to business strategy and the voice of customers

work on remedying such problems to attain the LSS goal. Structured problem-solving tools such as value stream mapping and statistical models may be used to reduce process and/or demand variability (Assarlind *et al.*, 2012; Schroeder *et al.*, 2008). However, the achievement of LSS is affected by several risks such as financial, technical, execution, commercial, and legal. Executable control or risk mitigation actions need to be taken to minimize the process/demand variability and maximize value creation to stakeholders in order to minimize these risks. Thus the aim of a structured problem-solving approach is to be able to have problems early and to develop appropriate solutions to the problems.

3.3 Exploring computational opportunities

Minimizing process variation is key in achieving and providing quality disaster relief services. Process variations may be as a result of work interruptions, multitasking, unpredictable demand, and the complexity of information (Locher, 2007). It is exceedingly important to find ways to minimize organizational wastes and improve process performance. In a survey study, Manville *et al.* (2012) identified two factors to this effect as project selection/prioritization and training/education. They note that data-driven decision making is crucial in achieving the goals of LSS. Disaster relief managers should to be cognizant of the need to explore computational opportunities and control wastes even under chaotic situations. They should also prioritize their needs and focus on the critical few activities that will create value in satisfying the needs of disaster relief victims. This emphasis would help in the allocation of limited resources available to meet the challenges posed by relief efforts.

3.4 Enabling conditions for lean and quality

LSS is customer driven and focusses on improving process performances and the quality of information across the value chain. According to Schroeder *et al.* (2008), higher levels of structural control with a special focus on outcomes, behavioral, and social dimensions tend to result in improved organizational performance. There are four essential elements of a balanced system namely leadership engagement, improvement specialists, strategic project selection, and structured method (Schroeder *et al.*, 2008). These elements collaboratively lead to e-successes in achieving LSS goals.

3.5 Achieving greater communication and endorsement

One of the primary objectives of LSS is to develop people and deploy structured processes to minimize wasteful activities. It is about value creation so it is important to be both efficient and effective. Communication and information sharing are important in meeting these objectives. Policy and decision makers need to have accurate, reliable, and timely information as well as appropriate channels of communication that will not hinder process performance.

4. Implementation of DRSCQM

Figure 2 illustrates the complexity in attempting to integrate the disaster relief life cycle and the CIMO logic on LSS principles. Early in the life of a disaster relief, the DRSCQM system appears relatively salient. At the various phases of the disaster relief process, there is need for process improvement. The complexity faced can be outlined as follows.

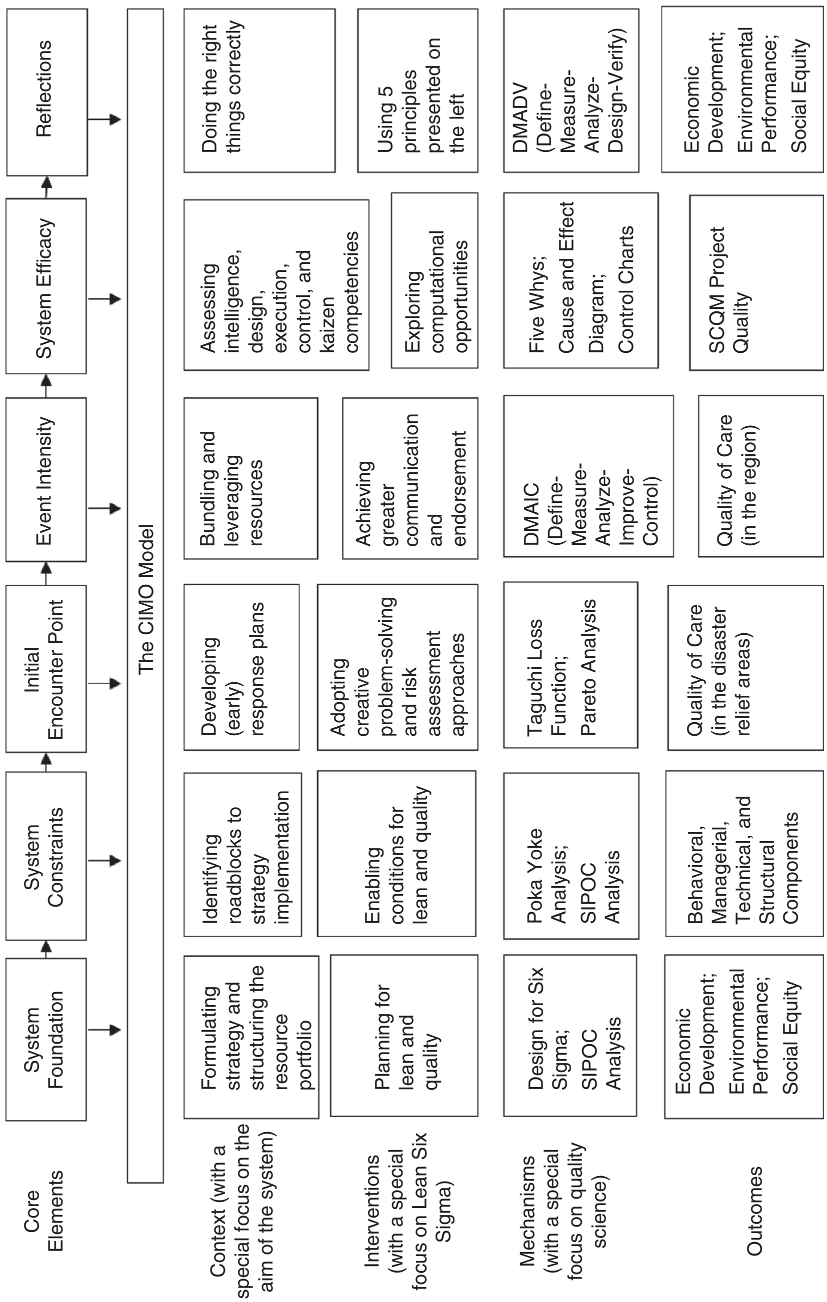


Figure 2.
Linking core elements to the CIMO model

4.1 System foundation

There is need to design quality into the DRSCQM system. This would involve the following phases:

- context: formulating strategies in the pre-event phase and identifying inhibitors;
- intervention: planning for lean and quality along the entire disaster relief life cycle;
- mechanisms: using solution packages such as design for Six Sigma and SIPOC (supplier, input, process, output, customer) analyses; and
- outcomes: setting up routine check points to evaluate and control system performance from four areas: safety and environment, quality, delivery, and economy.

The maturity grid introduced by Madu and Kuei (2012) could be used to facilitate the process. The maturity grid uses two axes namely "collaboration efficiency" and "collaboration effectiveness" to assess the performance of the organization. As noted by Kunz and Reiner (2012, p. 119), the former, "can be defined as the quantity of relief items delivered within a given budget" whereas the latter is about "timely delivery of the right relief items". For each axe, relief organizations may be classified into three categories based on their current capabilities, processes, and resources: laggard (L), mediocre (M), and world-class (W). As a result, the maturity grid has nine cells showing the levels of efficiency and effectiveness. The top performing relief organizations that are to be benchmarked are world-class in both collaboration efficiency and collaboration effectiveness. The maturity grid could thus be used to review and identify the current state and position of the relief organization, and to make a determination on the future state the relief organization should be in. Given the "as is" and "to be" states, policy makers and key players (e.g. non-governmental organizations) can evaluate alternative options and develop remedial actions that can move the organizational units from existing situations (e.g. good system foundation) into preferred ones (e.g. the great system foundation in the pre-event phase).

4.2 System constraints

Relief organizations/supply networks face the uncertainty in demand and supplies (e.g. voluntary contributions). They operate with limited resources and often have limited communication capabilities. Thus, there is a need to apply CIMO logic:

- context: identifying roadblocks to strategy implementation in the pre-event phase;
- intervention: enabling conditions for lean and quality deployment along the entire disaster relief life cycle;
- mechanisms: adopting ideas such as Poka Yoke analyses and SIPOC (supplier, input, process, output, customer) analyses; and
- outcomes: evaluating system conditions in the pre-event stage on a regular basis from four perspectives: behavioral, managerial, technical, and structural.

To deal with system constraints, a new paradigm that adopts the cost of quality (COQ) model is needed.

Juran popularized the use of the COQ model that is based on four cost constructs: prevention, appraisal, internal failure, and external failure. A proactive/preventive approach is necessary so that relief organizations/supply networks can minimize the detrimental effects of the more expensive external failures costs by getting things done right the first time. Prevention pays and proficiency is needed to deliver quality relief services. There are two phases in the disaster relief cycle namely mitigation and preparedness (Cozzolino, 2012; Altay and Green, 2006).

4.3 Initial encounter point(s)

At the initial stages of natural disaster encounter, it is crucial to have an active early response program that is based on strategic planning. This involves issues on the location of relief centers, supplies and logistics, community awareness, early warning signals, and communication and networking with other stakeholders. The aim of strategic planning here is to proactively plan and mobilize resources in a timely manner in the case of natural disasters.

The CIMO check list during the initial stages of natural disaster encounter is shown below:

- context: developing early response plans;
- intervention: adopting creative problem-solving and risk assessment approach;
- mechanisms: using models such as Taguchi Loss function and Pareto analyses to plan effectively; and
- outcomes: evaluating the requirements and needs of stakeholders in disaster-affected zones.

This check list ensures that problems are solved creatively and that efficiency and effectiveness are achieved in the delivery processes. Some of the problems addressed through this approach are:

- Can accurate forecasting, inventory control, warehousing, and transportation models be developed with respect to the different types of demand, supplies, and impact scenarios?
- How can policy makers and operations managers develop a simulation model to overcome "Nobody Knows" syndrome and improve the likelihood of success (e.g. meeting stakeholders' needs)?
- How can optimization techniques be used in the effective allocation of limited resources?

It is essential that these problems be addressed through the use of Monte Carlo simulation tools. This tool enables decision/policy makers to consider uncertainties and to evaluate alternative scenarios so that a better option can be selected wisely. It can be used in the pre-disaster phase where planning is essential. Optimization techniques may also be used in risk assessment of simulated events and scenarios (Falasca and Zobel, 2011). All these efforts help in improving the quality of decision making so better services can be delivered when natural disasters finally occur.

4.4 Event intensity

Effective management of disaster relief supply networks depends on factors such as demand, supply, logistics, and distribution. The demand for disaster relief supply chain intelligence competence has grown in recent years even with advanced technologies and mobile platforms. The CIMO template can be adopted here to benefit a wide array of stakeholders in disaster-affected areas. This is highlighted as follows:

- context: bundling and leveraging resources immediately in times of trouble;
- intervention: achieving greater communication and endorsement;
- mechanisms: using solution packages such as DMAIC; and
- outcomes: evaluating the actual fit between requirements and the needs of stakeholders in disaster-affected zones; and the dynamic capabilities of relief organizations.

Disaster relief operation should be people oriented. It demands the engagement of talented and skilled people and groups along a disaster relief supply chain to achieve a common goal. Participants in disaster relief operation need to speak a common language. Critical to quality (CTQ), in this context, is the language that every participant understands. Kunz and Reiner (2012), for example, report four CTQ variables: survivability, speed, safety, and sustainability. These variables are essential in disaster relief operations management.

4.5 System efficacy

World-class companies follow a systemic approach to SCM. Disaster relief organizations/supply networks need to employ the CIMO logic to establish a checklist. This could be done by evaluating:

- context: assessing the static and dynamic competencies in the following five areas: intelligence, design, execution, control, and kaizen (i.e. continuous improvement);
- intervention: exploring computational opportunities;
- mechanisms: using tools such as five whys, control charts, and cause and effect diagram; and
- outcomes: evaluating the static and dynamic conditions of the organization using the maturity grid.

Project management is important in achieving system efficacy. This entails knowledge of process improvements and scheduling of activities to ensure that due dates and schedules are met at minimum costs. Time is critical in disaster relief efforts. It is therefore imperative that attention be paid to project scheduling and management. Effective management of disaster relief supply chain quality depends very well on:

- demand forecasting and channel design;
- aggregate planning and optimization;
- supply chain network configuration; and
- transportation capacity, inventory planning, and scheduling.

A platform should be established to support knowledge and information sharing. This may require a change in the structure of the organization/supply network to support flat structure of organization/supply network and lateral flow of information. A well-coordinate system of networks is needed to respond swiftly to changes in dynamic environments.

4.6 Reflections

Sandwell (2011, p. 135) notes that "humanitarian managers should be constantly looking to acquire/customize management tools to fit their ever-changing needs." Relief organizations/supply networks should not simply adopt existing tools blindly. Rather, they need to adopt holistic view of their own activities and identify tools that may help them to become more efficient and effective. The CIMO logic may be helpful to that effect as follows:

- Context: doing the right things correctly and taking into account a holistic view of the relief environment. This would require the consideration of the socio-economic factors associated with disaster relief administration as well as the structural components and their relationships to the natural environment.
- Intervention: the intervention mechanism relies on waste control and management. It is important to be lean and also be green. This approach benefits from the LSS principles.
- Mechanisms: the mechanism here involves adopting the Six Sigma concept notably the DMADV.
- Outcomes: maintaining "the integrity of the social and environmental systems while reconfiguring human resources, management, technical platforms, and structural components to maximize their financial performance (Madu and Kuei, 2012, p. 15)".

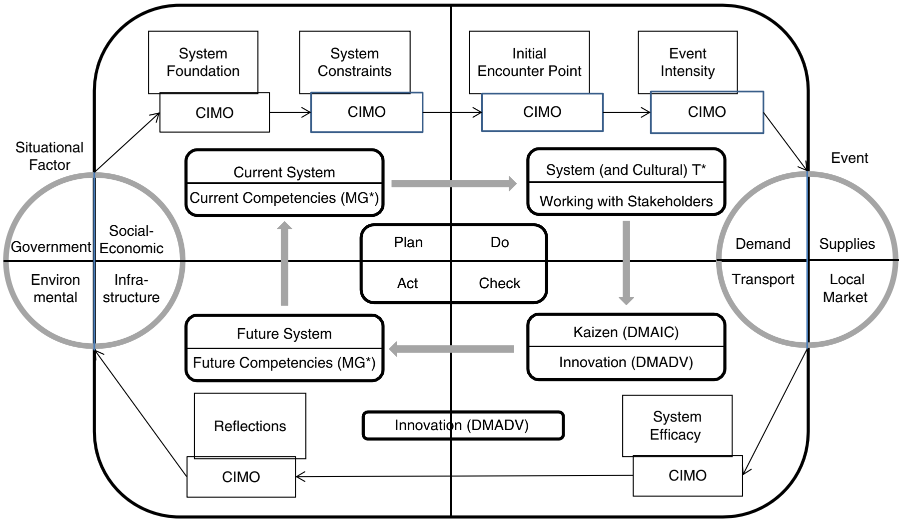
DRSCQM would require significant system-wide changes. Changes are not easily acceptable even when they are unavoidable. However, it is a necessity here if stakeholders intend to improve the quality of disaster relief efforts especially as they are faced with more disasters competing against limited resources.

5. Managing DRSCQM transformation

The real challenge in the disaster relief setting becomes how to manage the DRSCQM transformation. Figure 3 presents a conceptual map to aid in that process. The transformation process involves three loops:

- the PDCA (plan-do-check-act) feedback loop;
- the disaster relief life cycle; and
- the system and cultural transformation feedback loop.

The PDCA was introduced by Dr Walter Shewhart and popularized by Dr Edward Deming. The plan stage articulates details with respect to disaster relief "silent networks." The do stage explores the initial early responses and actual responses in times of trouble. Disaster events are assessed on four dimensions: demand, supplies, transport, and local market conditions. In the check stage, the strategic fit between the capacities of DRSCQM systems and the actual requirements of stakeholders is reviewed. Innovative as well as continuous improvement initiatives are activated to deliver quality disaster relief efforts. Everyone is engaged in either DMAIC or DMADV. Likewise, everyone is in a constant mode of self-assessment to achieve continuous improvement. The act stage involves large-scale system changes based on either DMAIC or DMADV exercises. As shown in Figure 3, this last stage, interacting with situational factors, is the precondition for the next round of design, operations, and improvement of DRSCQM system foundations.



Notes: MG*, Maturity Grid; T*, Transformation

Figure 3. Strategic views of Deming's plan-do-check-act cycle

The second phase shows that the traditional relief supply chain system must undergo an overhaul. Given the current position according to the maturity grid, a total transformation process consists of three components:

- A system transformation process that involves changing the DRSCQM process.
- Relationships with stakeholders must be changed.
- A cultural transformation process that demands re-educating the labor force to manage new structural changes based on LSS principles. A new DRSCQM entity emerges after this transformation and may hopefully be better than the existing system. Figure 3 could be used to track and trace achievements and areas for improvement and can help to assess overall performance of DRSCQM systems.

The third phase, discussed in the previous section, has six building blocks: system foundations, system constraints, sudden natural disaster encounter point(s), the intensity of disaster, the efficacy of the disaster relief supply chain systems, and reflections and ongoing issues.

Taking into account these three loops it is important to evaluate the new DRSCQM system and compare it to the legacy system. The goal is to continuously improve and to always be better. Each event will present new challenges and lessons learned will help to continuously improve, modify, and adapt the DRSCQM system.

6. Conclusion

Dr Edward Deming pointed out that, an example teaches nothing unless studied with the aid of a theory. In this paper, disaster relief life cycle is analyzed in the context of CIMO logic and LSS principles. The systemic and holistic procedure developed here views the environment of disaster relief as dynamic, complex, chaotic, and ever-changing and takes into account the fact that relief organizations' actions often involve a team of diverse specialists working on a project basis. Oftentimes, this is a result of the sudden nature of natural disasters since they are unplanned and may differ in terms of magnitude and intensity. Nevertheless, it is important to remain focussed even in times of chaos and natural disasters. Planning effectively and responding timely may help to optimize the limited resources that are available at the time and to deliver quality relief services to the disaster victims. A transformation process based on Dr Deming's PDCA cycle has also been proposed to show how a relief organization/supply chain can assess its current maturity level, react to it, develop more sustainable disaster relief practices, and propel the entire system to the right direction.

We believe that our theoretical frameworks will enhance the current knowledge base in DRSCQM literature and will also be helpful to manage disaster relief operations and supply chains.

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