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# A multiple objective optimization based QFD approach for efficient resilient strategies to mitigate supply chain vulnerabilities: The case of garment industry of Bangladesh <sup>☆,☆☆</sup>

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## ABSTRACT

With the upsurge of frequent disruptive events, organizations have become more vulnerable to the consequences of these disruptive events. As a result, the need for more resilient supply chain (SC) to mitigate the vulnerabilities has become paramount. Supply chain resilience (SCR) has been discussed in the literature and resilience index has been developed, but developing and selecting a portfolio of supply chain resilience capabilities in order to mitigate the vulnerabilities have not been studied. In this research we develop a 0–1 multi-objective optimization model based on QFD methodology. Our multi-objective method is interactive and interacts with the decision makers to choose the most satisfactory efficient portfolio of supply chain resilience strategies. We apply our methodology to three large ready-made garment (RMG) companies of Bangladesh. Results show that lack of materials (high dependence on imported materials), disruptions in utility supply, increased competition (and hence competitive pressure), impact of economic recession, and reputation loss are the top most vulnerabilities of Bangladesh RMG industry. The most preferred resilience strategies to mitigate the vulnerabilities are: back-up capacity, building relation with buyers and suppliers, quality control, skill and efficiency development, ICT adoption, demand forecasting, responsiveness to customers, and security system improvement. Theoretical and managerial implications of our study are included.

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## Introduction

Ready Made Garment (RMG) industry contributes hugely to Bangladesh's economy. It creates more than four million direct employment and several millions of indirect employment and accounts for 78.6 percent of countries export earnings [5]. RMG sector also immensely contributes in reducing the high rate of women unemployment in the country as 80 percent of the garments workers are women [5]. Thanks to the RMG sector, Bangladesh is also the second largest apparel exporter in the world.

Despite its huge potentials the industry is struggling with numerous Supply Chain (SC) disruptions [49,42]. The consequences of the disruptions are huge, for example, RMG industry of Bangladesh loses \$26.15 million per day due to problems in SC functions caused by political instability [1]. Moreover, the preferential access in U.S. market is cancelled because of the poor safety standard in production plants as building collapse in garment factory caused the death of more than

eleven hundred workers [37]. These disruptions have chain effect to all the members in SC network including the international buyers (retail chains) and suppliers. In the wake of such a critical state in RMG supply chain, *developing resilience capabilities is vital, which is the primary objective of this study.*

Resilience has been defined by a number of authors in a related manner. Vugrin et al. [99] define system resilience and resilience in general. The authors highlight that resilience is the ability of a systems to respond to a 'disruption' due to an event or set of events. Along the same vein Christopher and Peck [24], Ponomarov and Holcomb [81] and Jüttner and Maklan [53] define supply chain resilience as the 'capability of the supply chain to responds to *disruptions* and recover from them'. On the other hand Pettit et al. [79,80] developed a supply chain resilience framework by identifying seven categories of vulnerabilities and creating supply chain capabilities along 14 areas (sourcing, order fulfilment, capacity development; among others). The authors surmise that current level of vulnerabilities and capabilities must be assessed in order to ascertain the current level of resilience. Literature emphasizes that developing resilience capability is vital for organizations. It enables organizations to improve system performance [80,99], achieve sustainable competitive advantage [81], gain market share in competitive environments [90], and decreases vulnerabilities [53,79,80]. However current literature lacks in

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proposing the ways and means to achieve supply chain resilience capabilities. In this research we stress that *resilience capabilities of RMG supply chain of Bangladesh must be developed to mitigate organizations vulnerabilities*. In pursuing this research objective we introduce the concept of ‘supply chain resilience efficiency (SCREF)’ which has significant pedagogical importance.

It has been established that supply chain resilience capabilities has multiple dimensions (objectives). For example Pettit et al. [79,80] in their framework highlight 14 areas of supply chain resilience capabilities to be developed from order fulfilment, capacity development to financial strengths. From multiple objectives decision making (MODM) perspectives the supply chain resilience capabilities must be ‘efficient’ to mitigate vulnerabilities. While literature on efficiency approach in MODM and its applications in production/operations management area are plentiful (for example see, [63]; among many others), the notion of ‘supply chain resilience efficiency (SCREF)’ from multiple objectives perspective is novel.

In this research we define SCREF as follows:

- (i) resilience capability must be *resource efficient* (e.g. minimum cost of implementation), and
- (ii) portfolio of chosen resilience capabilities must be *efficient (or non-dominated)* from multiple objectives perspective [63].

We shall elaborate on (i) and (ii) later. It is observed that a number of logistics and SC related capabilities are discussed in the literature (for example; [80,38,81,90,24]; among many others) to develop SC resilience but most of those are conceptual studies and fall short of introducing the notion of resilience efficiency. Furthermore, in a state of uncertainty, dynamic changes and resource limitation, selection of optimal and efficient portfolio of resilience capabilities has not yet been addressed adequately in the existing SC literature.

While a number of approaches could be undertaken to achieve the research objective, this study has adopted Quality Function Deployment (QFD) [77,102] as a methodology to develop the resilience capabilities of the RMG supply chain of Bangladesh and find the optimal efficient portfolio of the resilience capabilities using a non-linear 0–1 programming approach. Literature on QFD approach is plentiful, which will be reviewed briefly in a later section. It is suffice to say that QFD enables organizations to be proactive to vulnerabilities mitigation rather than reactive and it is a proven technique for designing supply chain mitigation capabilities in such situations [34]. However we shall use Analytical Hierarchy Process (AHP) [86] within QFD for the analysis of data. It is important to note that methodologically our contribution lies as follows: we define supply chain resilience efficiency (SCREF) and find portfolio of efficient resilience capabilities for implementation using multiple objectives based non-linear 0–1 mathematical program.

It is noted that overall domain of our present study is Enterprise Risk management (ERM). Enterprise Risk management (ERM) has been defined in many different ways. However, one common theme of ERM is that it takes a ‘holistic and strategic’ approach to manage all risks that an organization faces [32,74]. A recent literature review [20] has found that Desheng Wu and David Olson are two of the most dominant contributors on ERM and various aspects of enterprise risk. One of their highly cited works is the application of ERM to assess credit worthiness in bank [106]. Wu and Olson [104], Wu et al. [107,108] have edited special issues of various journals on various aspects of ERM, ranging from risk methods and tools in operations, enterprise risk management in operations and business intelligence in risk management. Various other applications of ERM are available elsewhere [20] and hence will not be repeated here.

Our present research focusses on resilience capabilities of RMG supply chain of Bangladesh to mitigate supply chain vulnerabilities. Literature suggests that vulnerability is an ‘exposure to serious disturbance arising from risks within supply chain’ [78]. Hence our

present study is highly relevant to the supply chain aspect of enterprise risk management. There are applications of enterprise risk management (ERM) in supply chain. For example, Wu and Olson [105] developed a DEA based value at risk (VaR) model to manage supply risks, specifically vendor selection problem. Olson and Wu [75] presented a review of ERM in supply chain. Jiang et al. [50] developed a LOGIT model of job satisfaction to reduce supply chain risks. However, it has been mentioned before that we developed a new approach to find an optimal portfolio of efficient resilience capabilities to mitigate supply chain vulnerabilities.

In the next several sections we present the state of affairs of RMG industry of Bangladesh, relevant literature, methodology (QFD based mixed qualitative–quantitative approach), application in RMG industry, followed by the results. The paper concludes with the discussions & implications and conclusions.

## Background

Bangladesh is one of the leading exporters of Ready Made Garments (RMG) in the world. RMG industry is an economic propeller of Bangladesh and apparel exports stood-up at 19.90 billion US dollar in 2011 and marked Bangladesh as the second largest apparel exporter in the world [5]. Because of enormous economic importance of RMG in the economy of Bangladesh, smooth and efficient functioning of supply chain activities is crucial. But, the RMG supply chain is facing a climax situation owing to numerous challenges, such as, labour unrest for violation of human rights, poor wages, poor and hazardous working environment, political instability, interruption in utility supply especially power shortage, inefficiency in customs and port management, exchange rate fluctuation, disruption in timely supply of fabrics and other accessories, increased competition, inefficiency in operations, intensive competitive pressure, strict compliance code regarding social and environmental issues; among many others [49,22,42]. Furthermore, increased lead time and cost due to disruptions in procurement and shipment of goods, lack of linkages and co-ordination among related industries in the value chain, dependence on imported inputs, limited variety of finished products [42], fall of order because of global economic downturn are also issues of high concern for the RMG supply chain of Bangladesh. As a result of these disruptions the growth of RMG export from Bangladesh has fallen from 23% in 2005–2006 to 15% in 2008–2009 [22]. In such a situation it is crucial to find ways and means to make RMG supply chain resilient and sustainable. Previous researchers focused mainly on RMG competitiveness, the existing problems and challenges of the industry. Table 1 summarizes these briefly. However, the issue of making RMG supply chain resilient and efficient has not been investigated yet. This study aims to fill this gap in the literature.

## Literature review

### Supply chain vulnerabilities

Maintaining an effective Supply Chain (SC) has become challenging and difficult as the supply chains are inherently complex and in recent times are overwhelmed with disruptive events. These disruptive events make a supply chain vulnerable, as supply chain vulnerability is the susceptibility of the supply chains to the consequences of disruptive events [8,53]. Wagner and Neshat [101] posit that supply chain vulnerability is determined by the vulnerability drivers arising from demand side, supply side and supply chain design issues. Similarly, supply chain vulnerability may also arise from a number of factors such as, delay during transportation, port stoppages, frequent occurrence of natural disasters, weak communication, supply shortages, demand volatility, quality problem, operational issues and

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