Critical indices and model of uncertainty perception for regional supply chains: insights from a Delphi-based study

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Abstract

Purpose – The dynamic nature of uncertainty sources in regional operations represents supply chain management (SCM) imperatives to review uncertainty management frameworks on an ongoing basis with a view to identifying and prioritising critical indices of uncertainty for effective SCM. The purpose of this study is to identify the critical indices of uncertainty for regional supply chains and analyse how SCM practitioners perceive uncertainty.

Design/methodology/approach – This paper presents a Delphi-based study with a panel of 70 SCM experts from the Sultanate of Oman in the Gulf Cooperation Council (GCC) region. It applies three rounds of a Delphi exercise to identify, select and prioritise the critical indices of supply chain uncertainty perceived by panel experts. The thematic analysis also provides theorisations on the process for uncertainty perception and factors shaping perception.

Findings – A total of 39 uncertainty indices were identified from demand, supply, manufacturing, control, technology, competitive, project, transport and geological sources. The Delphi selection round captured the top 12 indices of experts. The research found an accumulative–aggregative duality that explains uncertainty perception and a cost–conformance–connection triadic set of factors underlying the perceived critical indices. Project uncertainty produced the top-ranked index in the final Delphi round.

Originality/value – This paper makes three main contributions. First, it offers a bottom-up based insight into supply chain uncertainty using the Delphi-based study and from a GCC perspective. Second, the research is unique in its focus on Oman and, third, it is of value for the international operations of GCC companies and for international firms with intentions of expanding, moving or outsourcing their operations to a GCC country such as Oman.

Keywords Supply chain management, Uncertainty, Operations strategy, GCC, Oman, Developing countries, Middle East, SCM framework

Paper type Research paper

1. Introduction

Supply chains typically span different regions of the world and practitioners grapple on a global scale with perceived uncertainty. Perceptions of uncertainty stem from questions:

> such as: what will my customers order, how many products should we have in stock, and will the supplier deliver the requested goods on time and according to the demanded specifications (Van Der Vorst and Beulens, 2002, p. 412)?

Such questions are indices (or measures) of perceived uncertainty that raise a myriad of supply chain management (SCM) challenges[1], and there is no panacea for confronting variability, volatility and vulnerability due to these questions. In light of these challenges, evaluations of supply chain uncertainty have a propensity to apply multi-criterion decision-making (MCDM) methods that inform option selection (Gao *et al.*, 2018; Mitra *et al.*, 2009), assess the relative impact (Gallear *et al.*, 2014; Koh and Gunasekaran, 2006) and adopt mitigation strategies (Farooquie *et al.*, 2017).

For regional supply chains "that conduct the majority of upstream and downstream activities in their home regions" (Rugman *et al.*, 2009, p. 385), SCM tends to reflect intra- and inter-regional strategies for economic development (Closs, 2015; Pei *et al.*, 2017) and environmental sustainability (Gao *et al.*, 2018; Marletto and Sillig, 2014). Subsequently,

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uncertainty in this context depends on varied influences and specificities as perceived by regional SCM practitioners and prioritisations that shape SCM design decisions. However, an analysis of SCM research suggests a gap in knowledge on how regional SCM practitioners perceive uncertainty and on the critical indices of uncertainty for regional supply chains. This constitutes the research gap for this study.

This paper aims to identify the critical indices of uncertainty for regional supply chains and analyse how SCM practitioners perceive uncertainty. Specifically, the research applies the widely used Delphi process in a study involving SCM practitioners from the Gulf Cooperation Council (GCC) region to advance research at the interface between SCM and operations strategy. Thus, the rationale of this research is that indices and theorisations relating to uncertainty perception may further enhance design decisions and strategy concerning the influences and specificities of SCM for regional supply chains.

In the area of managerial decision-making for supply chain uncertainty, researchers apply MCDM methods such as analytical hierarchical process and theory of constraint (Koh and Gunasekaran, 2006), data envelopment analysis (Gallear *et al.*, 2014), grey relational analysis (Farooquie *et al.*, 2017), interpretive structural modelling (Chand *et al.*, 2015) and fuzzy techniques (Mitra *et al.*, 2009; Wang and Durugbo, 2013). However, Delphi offers an appropriate MCDM approach for this study because it uniquely supports an iterative process allowing participants to revise choices, allows anonymity for true opinions to emerge, and supports high conflict situations involving multiple decision makers (Mukherjee *et al.*, 2018). In addition, Delphi is suitable for addressing the main aim of this study because it supports group consensus in the identification (and prioritisation) of issues and in the modelling of perceptions, such as supply chain uncertainty.

The Delphi process is widely used in SCM research to identify and prioritise research opportunities and for decision models. Previous areas of use include sustainable SCM (Reefke and Sundaram, 2017, 2018; Seuring and Müller, 2008), big data applications and understanding for SCM (Brinch *et al.*, 2018) and SCM for flexibility and excellence (Lummus *et al.*, 2005; Luo *et al.*, 2018). This study specifically applies an online version of the Delphi process (i.e. e-Delphi) for expert insights, anonymity and controlled feedback for the prioritisation of issues (Schmidt, 1997). Because the Delphi process relies on multiple rounds of systematic enquiry to reach panel consensus, a key challenge for using the process is striking a balance in the number of rounds used to gather opinions. It is for this reason that two or three rounds of polling are typically used in Delphi-based SCM studies (Lummus *et al.*, 2005; Luo *et al.*, 2018; Reefke and Sundaram, 2018). Too many rounds may raise commitment issues with the panel and too few rounds would produce underdeveloped conclusions. With this in mind, this article presents a three-stage Delphi-based study with SCM practitioners from the GCC region to confront the following research question:

RQ1. What are the critical indices of regional supply chain uncertainty?

RQ2. How do regional SCM practitioners perceive uncertainty in supply chains?

This study is relevant to regional SCM practitioners and researchers in two main ways. First, as an uncertainty assessment that replicates and updates research on indices of supply chain uncertainty but from the perspective of developing countries and specifically the GCC region. This assessment is a useful competence in setting parameters for SCM tools such as supply chain audits that are conducted to appraise supply chain operations (Childerhouse and Towill, 2004) and collaborative readiness assessments that inform decisions to admit/omit supply chain partners (Durugbo and Riedel, 2013). Second, as an uncertainty theorisation that offers knowledge to inform the setting of performance objectives for supply chain strategies. As a critical metric for success, supply chain strategies provide an important basis of competition that trigger firms to amalgamate operations strategy with contemporary marketing and business policies such as user-generated content, co-creation and brand influencers. It is for this reason that knowledge from related studies of supply chain uncertainty has been applied in supply chain planning that leverages competitive business models (Koh and Tan, 2006) and underscores relationship-building skills for SCM (Kwon and Suh, 2005).

The remainder of this paper is organised as follows. Section 2 presents the research background. Section 3 describes the research methodology. The findings of the research are presented in Section 4. Section 5 discusses the research findings and potential future research directions. Section 6 presents the conclusions.

2. Research background

2.1 Supply chain uncertainty: an overview

Supply chain uncertainty:

> [...] refers to decision making situations in the supply chain in which the decision maker does not know definitely what to decide as he is indistinct about the objectives; lacks information about (or understanding of) the supply chain or its environment; lacks information processing capacities; is unable to accurately predict the impact of possible control actions on supply chain behaviour; or, lacks effective control actions (non-controllability) (Van Der Vorst and Beulens, 2002, p. 413).

Due to the importance of supply chain uncertainty, there have been several attempts to create a holistic framework for identifying perceived sources and indices. As a pioneer in this respect and using the case of Hewlett-Packard's operations in the early 1990s, Davis (1993) identified suppliers, manufacturing and customers as three main sources of uncertainty that need to be considered for supply chain performance. Chen and Paulraj (2004) reviewed these sources to emphasise demand uncertainty associated with customers, supply uncertainty of suppliers and technology uncertainty due to the pace of technological innovation. Technology uncertainty has also been linked to manufacturer-supplier collaboration (Oh and Rhee, 2008) and buyer–supplier relationships (Hoyt and Huq, 2000). Ho *et al.* (2005) critiqued the extant literature on supply chain uncertainty and developed a set of uncertainty scales based on the uncertainty sources identified in Davis (1993). Their development process followed a structured approach to identifying uncertainty measures in three stages. The first stage, construction, involved using literature to identify entries and critically evaluate these entries in industrial and academic focus groups. The second, purification, entailed analysing entries using approaches such as principal component analysis. The final, scale confirmation, concerned testing the entries using methods such as confirmatory factor analysis and structural equation modelling. In Mason-Jones and Towill (1998) and Childerhouse and Towill (2004), the work of Davis (1993) was built on and used in formulating the uncertainty circle model with four main uncertainty sources: the supply side, the manufacturing process, the control systems, and the demand side. Vijayasarathy (2010) also identified competitive uncertainty that influences performance rewards. The reader is referred to Simangunsong *et al.* (2012) for a review, theorisation and discussion on the concept of supply chain uncertainty.

Planning shrinks uncertainty (Dvir *et al.*, 2003) and the various sources of uncertainty identified in the SCM literature provided useful focal points for practitioners during forecasting to detect potential supply chain anomalies and derive alternative supply chain configurations. Here, MCDM methods aid forecasts and foresight to enhance product recovery (Gao *et al.*, 2018), delivery performance (Farooquie *et al.*, 2017; Gallear *et al.*, 2014; Koh and Gunasekaran, 2006), industrial competitiveness (Chand *et al.*, 2015; Mitra *et al.*, 2009) and business strategy (Koh and Tan, 2006).

Even though forecasts tend to work very well for a while, forecasters were usually aware that a change in prioritised indices of supply chain uncertainty could suddenly break historic patterns and create new trends (Van Der Vorst and Beulens, 2002). Thus, critical indices of supply chain uncertainty required review on an on-going basis to reflect evolving trends and statuses of supply chain relationships, configurations and performance in international operations. Such review was particularly needed due to emerging trends in supply chains (e.g. big data analytics (Brinch *et al.*, 2018) and sustainability (Reefke and Sundaram, 2017, 2018; Seuring and Müller, 2008)) and in society (e.g. globalisation in world economies and economic diversification in the GCC region (Al-Shboul, 2017; Bayraktar *et al.*, 2009)).

2.2 The Gulf Cooperation Council region and supply chains: the context

With about 30% of the world's known oil reserves (0.496 out of 1.665 trillion bbl), the GCC region has strategic global importance and consists of six Arab and Islamic countries: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates. As shown in Table 1, this region currently accounts for 0.0062% of the global population and 0.0079% of the global labour force but delivers 0.0264% of global gross domestic product (GDP). Previously considered mainly as a crossroads of trade between Europe and Asia, an awareness of oil reserves turned the GCC and Middle Eastern region into a market in its own right (Stewart, 1961) with several major multinational corporations establishing a foothold in several GCC and Middle Eastern countries as early as the 1930s (Mellahi *et al.*, 2011). However, recent years have witnessed deep changes in the GCC region that have been largely influenced by the volatility of oil prices due to conflict in certain countries, socio-political pressures for economic reform and job creation in the entire region, and more significantly, forward-looking plans to curb over-reliance on oil. These challenges are the stimuli for transformations by GCC government policies that involve diversifying the region's economies away from oil dependence to tourism, commercial and industrial activities. Construction projects are heavily invested in by GCC governments in a boom that started in the mid-1970s (Narayanaswami, 2017). Other areas of infrastructure and public services such as utilities and health care and the telecommunications sector, also share substantial portions of governmental budgets. Consequently, and more importantly, strategically, world trade remains a key route for transforming GCC economies on a global scale (Hausman *et al.*, 2013) with local firms financing their supply chain expansions and production plant modernisation investments through borrowing from banks. Overall, companies in the GCC region are continuously exploring avenues to expand into global markets (Badri, 1999) and have wider involvement in global innovation networks (Mellahi *et al.*, 2011).

However, as regional supply chains of the GCC open up to global markets, they are becoming more complex and SCM researchers increasingly accentuate three unconventional sources of supply chain uncertainty. Firstly, ongoing infrastructure projects to scale up regional operations have been plagued by a range of *project-related* sources of uncertainty with technical, financial, human resource implications that need to be factored into project estimates and other operations in the region (Dayan *et al.*, 2012; Zwikael and Sadeh, 2007). *Transport uncertainty* that impacts regional movements of supply chain resources (Narayanaswami, 2017) and *geological uncertainty* due to volatility of hydrocarbon prices/costs/demands (Maddah *et al.*, 2014), are other forms of variability

Table 1 Overview of GCC countries (based on factbook, CIA publications, US Government documents, 2017)

Countries	GDP ($bn)	Labour force (millions)	Imports ($bs)	Exports ($b)	Population (July 2017 est.)	Crude oil - proved reserves (Jan. 2018 est.) (billion bbl.)
Bahrain	70.4	0.83	13.96	14.33	1,410,942	0.1246
Kuwait	291.5	2.70	29.36	54.09	2,875,422	101.5
Oman	186.6	2.26	22.71	31.90	4,613,241	5.373
Qatar	340.6	1.95	26.69	56.26	2,314,307	25.24
Saudi Arabia	1774.0	13.80	136.80	231.30	28,571,770	266.2
United Arab Emirates	686.8	5.34	241.30	314.70	6,072,475	97.8
TOTAL	3349.9	26.88	470.82	702.58	45,858,157	496.2376
WORLD	127,000	3382	1,689,000	1,731,000	7,405,107,650	1665
% of World	0.0264	0.0079	0.0003	0.0004	0.0062	0.2980

associated with GCC-based operations that pose unique environment-wide challenges for research and industry.

Generally, the GCC region is increasingly becoming home to many of the world's largest multi-national corporations, most of which enjoy sustained profitability from their regional supply chains (Mellahi *et al.*, 2011); making it a fertile area for studying challenges that confront SCM practitioners. Indeed, several recent sources (Faghih and Reza, 2018; Mellahi *et al.*, 2011; Zahra, 2011) have raised awareness of the potential for novel research areas to explore pertinent and contemporary management challenges in the GCC region. With this in mind, the motivation for this study is to use a GCC perspective to offer a conceptual model of uncertainty perception for information environments that improve decision-making situations in the regional supply chain. The next section outlines the research methodology for a Delphi-based study with SCM practitioners based in the GCC region.

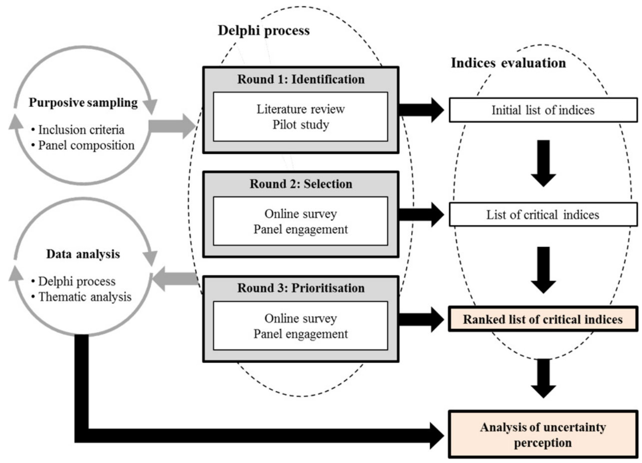
3. Research methodology

The Delphi process is a well-established tool for research (Okoli and Pawlowski, 2004), decision-making (Van De Ven and Delbecq, 1974) and forecasting (Ludwig, 1997) that aims to "obtain the most reliable opinion consensus of a group of experts by subjecting them to a series of questionnaires in depth interspersed with controlled opinion feedback" (Dalkey and Helmer, 1963, p. 458). It was developed in the late 1940s at the Rand Corporation (Klassen and Whybark, 1994) and is intended for use in analysing complex problems through a round of questions between scientists (researchers) and subject matter experts (practitioners). The process involves a series of steps to select qualified experts, to develop a protocol for enquiry on a subject and analyse findings from the enquiry with the goal of prioritising or forecasting issues related to the subject. Thus, the selection and participation of Delphi panel experts is a significant feature of the process with proponents of the process recommending a careful selection of panel along with anonymity among panel experts and controlled feedback (MacCarthy and Atthirawong, 2003; Schmidt, 1997).

Using purposive sampling (Barbour, 2001), this study adopts three rounds of uncertainty identification, selection and prioritisation with 70 carefully chosen SCM experts from the Sultanate of Oman in the GCC region, as shown in Figure 1. The elicitation of experts was based on an objective inclusion set of criteria to establish a representative sample for reaching consensus (Reefke and Sundaram, 2018). The criteria were that each expert had to possess at least 2 years' professional experience and continued interest in SCM.

The research applied thematic analysis (Boyatzis, 1998) after the Delphi process to methodically understand and identify patterns from the collected data. The intention was to analyse how SCM practitioners perceive uncertainty. The analysis involves deciphering and interpreting common themes of the ranked critical indices of supply chain uncertainty. The focus was on identifying factors shaping perception based on analysing the sentences that describe the uncertainty, e.g. "rate of new product introduction" and "replacing supplier of critical material". Part of the analysis is also devoted to theorising on the process for uncertainty perception and knowledge for this

Figure 1 Flow chart for research methodology



aspect of the analysis stems from observing the entire Delphi process.

The Delphi panel comprises the following experts: 9 consultants and academic practitioners, 14 logistics, transport and services managers, 15 construction managers, 16 manufacturing and industrial engineers and 16 public sector managers. SCM expertise and knowledge from experts are from fields of logistics, education, oil and gas, utilities, aviation, manufacturing, public services, etc. Participants were identified and contacted based on referrals, mailing lists and social media (WhatsApp) special interest groups. The next subsections present details on how the three Delphi rounds were structured.

3.1 Round 1: identification

The goal of the first round was to generate an initial list of uncertainty indices for subsequent Delphi stages and 15 experts took part in discussions. In preparation for this round, the literature review was conducted to identify a set of potential indices for supply chain uncertainty sources. These indices were used in the development of the questionnaire applied during the subsequent rounds of the Delphi study. During these subsequent rounds, the questionnaire was crosschecked by colleagues and a pilot study was conducted with three academic researchers and three industrial practitioners, in line with similar studies (Klassen and Whybark, 1994; MacCarthy and Atthirawong, 2003). These pre-tests aided in delivering clarity and consistency in the substance, structure and staging of questions. A "shuffle option order" feature of the adopted online survey service was used to randomise the order in which indices were presented to panel experts. This ensured a repeated measures research design was supported with counterbalancing to limit order effects.

3.2 Round 2: selection

During the second round, opinions were solicited and obtained from all 70-panel experts on the indices of supply chain uncertainty that they perceived as most important for regional operations. The goal of the second round was to elicit the critical indices of supply chain uncertainty. The panel was presented with a set of potential indices from Round 1 and

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asked to identify the 10-12 most important indices. The estimated completion time for the questionnaire was 10–15 min. An option was provided for experts to suggest extensions to the identified 39 indices or to make additional comments or recommendations if desired. The second round was completed over a two-month period and the collated opinion data was tallied for use in the third round. Engagement through the network of referrals and email reminders were used to enhance the response rate.

3.3 Round 3: prioritisation

The third prioritisation round involved 57 panel experts, i.e. 81.4% of Round 2 panellists. The goal of this third round was to rank the critical indices of supply chain uncertainty. The questionnaire used in this round was a 12-index list derived from the first round. Tallied responses from the previous round determined the 12-index list. Similar conditions to the first round were also applied, i.e. pre-tests for substance, structure and staging of questions; randomised order of indices for counterbalancing to limit order effects; and two-month timeframe and use of engagement/reminders to improve response rate. However, unlike the previous round, anonymous voting and ranking based on the widely used nominal group process (Delbecq *et al.*, 1975; Delbecq and Van de Ven, 1971) was incorporated to facilitate and assess consensus on critical supply chain uncertainty indices. This process involved using a tick box grid to ensure indices were ranked from 1st to 12th. Using a "limit to one response per column" feature of the online survey service, experts were required to give opinions on the comparative importance of each index. Estimated completion time was 8–10 min.

4. Research findings

This section presents the Delphi findings of this study. It begins with the findings of the first two rounds followed by results of the prioritisation during the third round. The section then outlines the model of uncertainty perception derived from the Delphi-based analysis.

4.1 Identification and selection of uncertainty indices

Round 1 identified 39 different indices. Using these uncertainty indices, Round 2 elicited dichotomous responses from panel experts and the tallied responses were analysed using frequency values (*f*), means of frequencies (μ) ranging from 0 to 1, as summarised in Table 2. The table contains frequency values that range from 8 (μ = 0.1143) to 34 (μ = 0.4857) of tallied responses. The table shows complete coverage in regard to selections for the full range of uncertainty indices presented to the panel experts. The next subsections detail panel selections according to the uncertainty indices identified from the SCM literature.

4.1.1 Demand uncertainty

Demand (customer and distribution) uncertainty is due to the unpredictable variations in the quality, quantity and timing of demand that is experienced across the supply chain (Davis, 1993) and the distribution variations due to customer order distribution lead time (Van Der Vorst and Beulens, 2002). This relates to the amount of forecast error, i.e. the difference between actual demand and forecast demand (Fynes *et al.*, 2004). Its indices are (Bhatnagar and Sohal, 2005; Chen and Paulraj, 2004; Davis, 1993; Fynes *et al.*, 2004; Gaur *et al.*, 2007; Ho *et al.*, 2005; Hoyt and Huq, 2000; Longinidis and Georgiadis, 2011; Paulraj and Chen, 2007; Prater *et al.*, 2001):

- D1 – rate of new product introduction;
- D2 – unexpected product demand;
- D3 – different sales channels;
- D4 – sharing demand forecast with customer;
- D5 – variety in distribution channels;
- D6 – changes in distribution channels;
- D7 – changes in product life-cycle;
- D8 – product variety; and
- D9 – changes in customer orders.

Because D2 and D9 were ranked 1st and 2nd overall, with μ scores of 0.4857 and 0.4143, respectively, they were marked for inclusion in the next Delphi round. Very low μ scores in the demand uncertainty category were recorded by D1 (0.1571) and D4 (0.1714) with rankings at 35th and 32nd, respectively.

4.1.2 Supply uncertainty

Supply (delivery) uncertainty is triggered by supplier performance variability and inconsistency that result in delayed, deficient or defective deliveries (Davis, 1993). It is brought about by machine breakdowns, downtimes during manufacturing, quality and yield problems, order-entry errors, forecast inaccuracies or logistical malfunctions (Fynes *et al.*, 2004). It is operationalised using the following indices (Bhatnagar and Sohal, 2005; Chen and Paulraj, 2004; Davis, 1993; Fynes *et al.*, 2004; Ho *et al.*, 2005; Paulraj and Chen, 2007):

- S1 – different quality of critical material;
- S2 – replacing supplier of critical material;
- S3 – number of critical material suppliers;
- S4 – availability of reverse logistics;
- S5 – different material supply lead-time;
- S6 – complexity of critical material;
- S7 – complexity of procurement technology for critical material;
- S8 – limited time for material procurement;
- S9 – challenges for delivering critical material;
- S10 – pressure for on-time delivery; and
- S11 – delay of critical material delivery.

In this source, S10 and S11 were ranked 2nd (jointly with D8) and 4th overall with μ scores of 0.4143 and 0.4000, respectively. Both were marked for inclusion in the subsequent Delphi round. Similarly, S8 which ranked 8th with μ value of 0.3429 was advanced to the next Delphi round. The lowest ranking indices in this grouping were S4 and S6 with both jointly ranked 32nd (μ scores of 0.144).

4.1.3 Manufacturing uncertainty

Manufacturing (process) uncertainty is concerned with volatility in process performances caused by unreliable manufacturing and production processes (Chen and Paulraj, 2004; Davis, 1993). This form of unpredictability results in poor production yields, scraps and write-offs (Van Der Vorst and Beulens, 2002). The literature suggests the following indices (Bhatnagar and Sohal, 2005; Chen and Paulraj, 2004; Davis, 1993; Fynes *et al.*, 2004; Ho *et al.*, 2005; Paulraj and Chen, 2007):

- M1 – effects of changes in preparation on the production process;
- M2 – types of spares and parts for products;

Table 2 Indices of supply chain uncertainty from literature

Supply chain uncertainty	Uncertainty indices	Frequency	Mean	Variance	Overall rank
Demand (customer and distribution) uncertainty	Rate of new product introduction (D1)	11	0.1571	0.134	35
	Unexpected product demand (D2)	34	0.4857	0.253	1
	Different sales channels (D3)	13	0.1857	0.153	29
	Sharing demand forecast with customer (D4)	12	0.1714	0.144	32
	Variety in distribution channels (D5)	16	0.2286	0.179	22
	Changes in distribution channels (D6)	20	0.2857	0.207	15
	Changes in product life-cycle (D7)	20	0.2857	0.207	15
	Product variety (D8)	15	0.2143	0.171	25
	Changes in customer orders (D9)	29	0.4143	0.246	2
Supply (delivery) uncertainty	Different quality of critical material (S1)	21	0.3000	0.213	13
	Replacing supplier of critical material (S2)	19	0.2714	0.201	18
	Number of critical material suppliers (S3)	14	0.2000	0.162	27
	Availability of reverse logistics (S4)	12	0.1714	0.144	32
	Different material supply lead-time (S5)	21	0.3000	0.213	13
	Complexity of critical material (S6)	12	0.1714	0.144	32
	Complexity of procurement technology for critical material (S7)	20	0.2857	0.207	15
	Limited time for material procurement (S8)	24	0.3429	0.229	8
	Challenges for delivering critical material (S9)	16	0.2286	0.179	22
	Pressure for on-time delivery (S10)	29	0.4143	0.246	2
	Delay of critical material delivery (S11)	28	0.4000	0.243	4
Manufacturing (process) uncertainty	Effects of changes in preparation on the production process (M1)	13	0.1857	0.153	29
	Types of spares and parts for products (M2)	10	0.1429	0.124	36
	Availability of spares and parts for products (M3)	19	0.2714	0.201	18
	Regular redesign for products (M4)	8	0.1143	0.103	37
	Number of product items changed per redesign (M5)	19	0.2714	0.201	18
Control (planning) uncertainty	Information accuracy (C1)	25	0.3571	0.233	7
	Information through-put times (C2)	8	0.1143	0.103	37
	Information availability and transparency (C3)	24	0.3429	0.229	8
Technology (platform) uncertainty	Quick technology changes in industry (T1)	23	0.3286	0.224	10
	Ability to keep up with technology changes (T2)	22	0.3143	0.219	11
	The rate of process obsolescence in industry (T3)	8	0.1143	0.103	37
Competitive (rivalry) uncertainty	Change rate of competitors with comparable/ substitute products (V1)	16	0.2286	0.179	22
	Entry rate of new competitors with comparable/substitute products (V2)	14	0.2000	0.162	27
Transport (logistics) uncertainty	Changes in the state of petroleum exploration (G1)	13	0.1857	0.153	29
	Changes in nature (G2)	19	0.2714	0.201	18
Geological (fuel) uncertainty	Availability of transport infrastructure (R1)	22	0.3143	0.219	11
	Availability of different types of transport (R2)	15	0.2143	0.171	25
Project (program) uncertainty	Changes to cost of projects (P1)	27	0.3857	0.240	5
	Changes to duration and quality of projects (P2)	26	0.3714	0.237	6

- M3 – availability of spares and parts for products;
- M4 – regular redesign for products; and
- M5 – number of product items changed per redesign.

Manufacturing uncertainty indices were not marked for inclusion in the 2nd round because none of them made the top 12 list. M3 and M5 toped this category with joint ranking of 18th overall and μ score value 0.2714. M4 was the lowest ranked uncertainty indicator for this round of the Delphi study at 37th with an overall μ score of 0.1143.

4.1.4 Control uncertainty

Control (planning) uncertainty is a result of unpredictable and unknown variations of system controls with supply chains (Childerhouse and Towill, 2004; Mason-Jones and Towill, 1998; Sanchez-Rodrigues *et al.*, 2008). This is caused by factors such wrong decision rules and stale, noisy or incomplete information. It is operationalised using the following items (Vorst *et al.*, 1998; Van Der Vorst and Beulens, 2002):

- C1 – information accuracy;
- C2 – information through-put times; and
- C3 – information availability and transparency.

C1 and C3 were marked for inclusion in the subsequent Delphi round because they ranked 7th and 8th with μ scores of 0.3571 and 0.3429, respectively. In contrast, C2 ranked joint last overall (with M4), i.e. 37th with an overall μ score of 0.1143.

4.1.5 Technology uncertainty

Technology (platform) uncertainty is an antecedent of strategic supply management initiatives (Auster, 1992; Oosterhuis *et al.*,

2011) that represents fuzziness in selections of suitable technology platforms (Koh and Tan, 2006). It increases with firms' aspirations to remain innovative and to maintain close coordination with supply chain partners. Technology uncertainty in this context relates to the technology changes within an industry sector (Chen and Paulraj, 2004; Fynes *et al.*, 2004; Hoyt and Huq, 2000; Oh and Rhee, 2008) as opposed to technology changes in society. Its indices are (Chen and Paulraj, 2004; Oosterhuis *et al.*, 2011; Paulraj and Chen, 2007):

- T1 – quick technology changes in industry;
- T2 – ability to keep up with technology changes; and
- T3 – rate of process obsolescence in industry.

Two technology uncertainty indices, i.e. T1 and T2 progressed to the next round of the study by virtue of ranking 10th and 11th with μ scores of 0.3286 and 0.3143, respectively. Contrastingly, T3 was also joint last along with M4 and C3 at 37th with an overall μ score of 0.1143.

4.1.6 Competitive uncertainty

Competitive (rivalry) uncertainty covers variability associated with rival firms, potential entrants into industry and potential merger and acquisition activities (Miller, 1992; Rao and Goldsby, 2009; Wernerfelt and Karnani, 1987). Uncertainty of this kind tends to cause firms to adopt retaliatory or mimicry strategies to maintain competitiveness. Items for measuring used as competitive uncertainty indices are (Vijayasarathy, 2010):

- V1 – change rate of competitors with comparable/substitute products; and
- V2 – entry rate of new competitors with comparable/substitute products.

Both indices were not eligible for the subsequent round due to their modest showings at 22nd and 27th with μ values of 0.2286 and 0.2000, respectively.

4.1.7 Transport uncertainty

Transport (logistics) uncertainty is variability in the movements of supply chain resources due to defective transportation modes, lack of carriers or scheduling and routing deficiencies (Sanchez-Rodrigues *et al.*, 2008; Sanchez-Rodrigues *et al.*, 2010a, 2010b). This impacts fleet management and infrastructure, capacity utilisation and transport network management. It is operationalised using two indices (Narayanaswami, 2017):

- R1 – availability of transport infrastructure; and
- R2 – availability of different types of transport.

R1 was marked for inclusion in the next round because it ranked 11th with μ score of 0.3143, whereas *R2* was excluded because it was ranked 25th by the panel with μ score of 0.2143.

4.1.8 Geological uncertainty

Geological (fuel) uncertainty is volatility in hydrocarbon prices/costs/demands that influences the ability of supply chain partners to function. This is due to exogenous factors, e.g. exploration/exploitation contracts and regional policies (Zhang and Dimitrakopoulos, 2018), and endogenous variables such as optimised processes for hydrocarbon mining, blending, processing and transportation (Montiel *et al.*, 2016; Montiel and Dimitrakopoulos, 2015) which determine the quality and quantity of petroleum products used in supply chains (Steinberg and Tomi, 2010). It is operationalized using indices for (Maddah *et al.*, 2014):

- G1 – changes in the state of petroleum exploration; and
- G2 – changes in nature.

G1 and G2 were not marked for inclusion in the subsequent round because they ranked 29th and 18th with μ values of 0.1857 and 0.2714, respectively.

4.1.9 Project uncertainty

Project (programme) uncertainty is variability in the objectives, resources, task and deliverables associated with a project (Cleden, 2017; De Meyer *et al.*, 2002; Perminova *et al.*, 2008). This variability has technical, financial and human resource implications for projects conducted by supply chains and need factoring into project estimates, partner selection, location decisions, etc. Indices for project uncertainty identified by the study are (Dayan *et al.*, 2012; Zwikael and Sadeh, 2007):

- P1 – changes to cost of projects; and
- P2 – changes to duration and quality of projects.

Both indices, i.e. P1 and P2, were high in the selections of experts, ranking 5th and 6th with μ values of 0.3857 and 0.3714, respectively.

4.2 Prioritisation of uncertainty indices

C1, P2, D9, T1, P1, S10, S11, T2, D2, R1, S8 and C3 were the top 12 uncertainty indices from the 2nd Delphi round. During the 3rd round, the rankings ascribed to these indices by the 57 experts were collated and subsequently analysed using metrics for the mean rank, variance of rank (D^2), as summarised in Table 3. The top three rated indices were P1, i.e. changes to cost of projects (5th in Round 2), C3, i.e. information availability and transparency (8th in Round 2), and P2, i.e. information accuracy (6th in Round 2). Although rated second overall in this round, C3 had the highest top-placed rating with the 1st ranking for 11 out of 57 (19.3%) panel lists and the highest top-three rating with coverage by 23 out of 57 (40.4%) panel lists. D2 had no 1st place ranking, whereas T2 had the lowest top-three rating with selection by 7 out of 57 (12.3%) panel lists.

Similarly, the bottom three rated indices were S8, i.e. limited time for material procurement (8th in Round 2), T1, i.e. quick technology changes in industry (10th in Round 2), and D2, i.e. unexpected product demand (1st in Round 2). Among the panel lists, D2 was rated last 8 out of 57 (14.0%) making it the highest bottom-placed measure, and T1 had the least bottom-three rating with coverage by 32 out of 57 (56.1%) panel lists. S11 had no bottom-placed rating and C1 had the least bottom-placed rating with marked by 12 out of 57 (21.1%) panel lists.

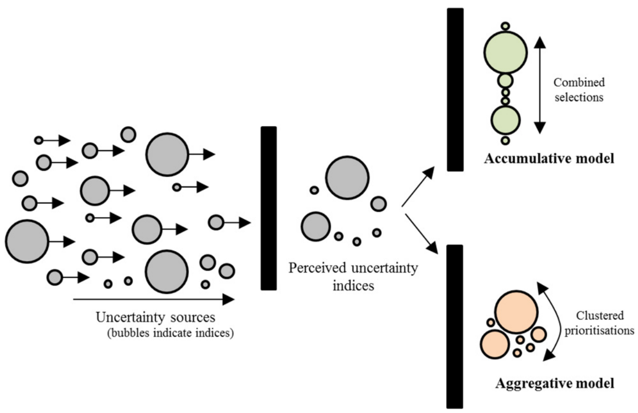
4.3 Analysis of uncertainty perception

This subsection presents the findings on how SCM practitioners perceive uncertainty. It theorises on the process for uncertainty perception based on the Delphi process and identifies factors shaping perception based on the thematic analysis of ranked critical indices of supply chain uncertainty.

Table 3 Indices of supply chain uncertainty from literature

Supply chain uncertainty	Mean of rank	Variance of rank	Overall rank
Changes to cost of projects (P1)	5.3860	10.170	1
Information availability and transparency (C3)	5.6667	15.976	2
Information accuracy (C1)	5.7895	14.098	3
Delay of critical material delivery (S11)	6.1579	10.921	4
Changes to duration and quality of projects (P2)	6.4211	11.427	5
Pressure for on-time delivery (S10)	6.4211	10.462	6
Changes in customer orders (D9)	6.4737	13.754	7
Availability of transport infrastructure (R1)	6.6667	13.155	8
Ability to keep up with technology changes (T2)	7.0175	9.839	9
Limited time for material procurement (S8)	7.1053	10.632	10
Quick technology changes in industry (T1)	7.2456	10.296	11
Unexpected product demand (D2)	7.6491	9.625	12

Figure 2 Aggregative and accumulative models of uncertainty perception



4.3.1 Processes for uncertainty perception: the aggregative – accumulative duality

Using insights from the Delphi process, this subsection theorises on uncertainty perception, as shown in Figure 2, based on the different outcomes from Round 2 and Round 3 of the Delphi study. These theorisations focus on the consensus reached at different stages of both rounds. Consensus for Round 2 centres on combining selections perceived by experts, whereas consensus for Round 2 involve clustering prioritisations presented by experts.

The first theorisation is an "accumulative model" positing that practitioners' perceptions of uncertainty can be ascertained from a sum of key SCM questions. It suggests a perception process, which identifies and summates various sources of uncertainty perceived according to the orientation of perceivers. Orientation implies the beliefs, attitudes and expectations that influence the aspirations and missions of individuals. In a SCM context, attitudinal and perceptual factors shape the orientation of practitioners within relationships for confronting SCM complexities (Durugbo and Riedel, 2013; MacCarthy and Atthirawong, 2003; Schmidt, 1997). The second round of the Delphi study, which requires experts to rate indices based on their orientations for critical indices, supports this theorisation. These ratings by experts present an instance of how a holistic picture of uncertainty emerges by accumulatively factoring indices according to decision-making situations. During the second round of the Delphi process, elicited responses reveal the uncertainty perception of practitioners concerning the critical indices of supply chain uncertainty. For accumulation, the inputs are the orientations and knowledge on supply chains whereas the output is an accumulated set of responses that reflect broad coverage of uncertainty sources. Figure 3 presents stacked columns of the tallied responses indicating ratios between wholes and parts of different groups of SCM practitioners in the study. The figure shows how scores for each group accumulatively show the range and magnitude of uncertainty for the regional supply chain.

The second theorisation is an "aggregative model" indicating that uncertainty perceptions by managers can be established based on understanding the degree of importance of key SCM questions. The model posits that a holistic picture of critical uncertainty indices involves an ordering and assemblage of the disparate indices by perceivers. This aggregative process involves a mentalisation process to conduct pointwise (single), pairwise (double) or listwise (multiple) comparisons of indices and to predict the impact of possible control actions for such indices on supply chain behaviour. Mentalisation means "trying to understand mental states, ours and other people's" (Churchman, 2016; p. 163) and this process guides experts in formulating strategies for coordination and information sharing. During aggregation, the inputs are the orientations and knowledge on supply chains much like the accumulation. However, unlike the accumulative model, the aggregative model involves mentalisation that generates an aggregated set of ranked responses that reflect collective judgement on critical uncertainty indices. In the third round of the Delphi process, ranked responses reveal the uncertainty perception of practitioners concerning the critical indices of supply chain uncertainty. Figure 4 outlines radar charts with markers of the mean ranked responses for different groups of SCM practitioners in the study. The figure shows the overall ranking for uncertainty indices, which is an aggregate of the different rankings. Considered in isolation, ranked responses from groups reflect partial judgement on priorities. In contrast, aggregated rankings provide collective judgement, depending on appropriate sampling and weightings, for a more complete full picture of the *status quo*.

Figure 3 Comparison of tallied selections for uncertainty indices among SCM practitioners

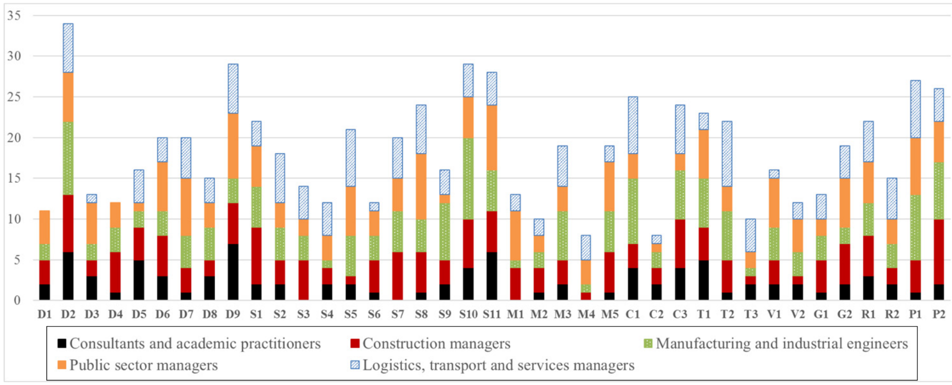
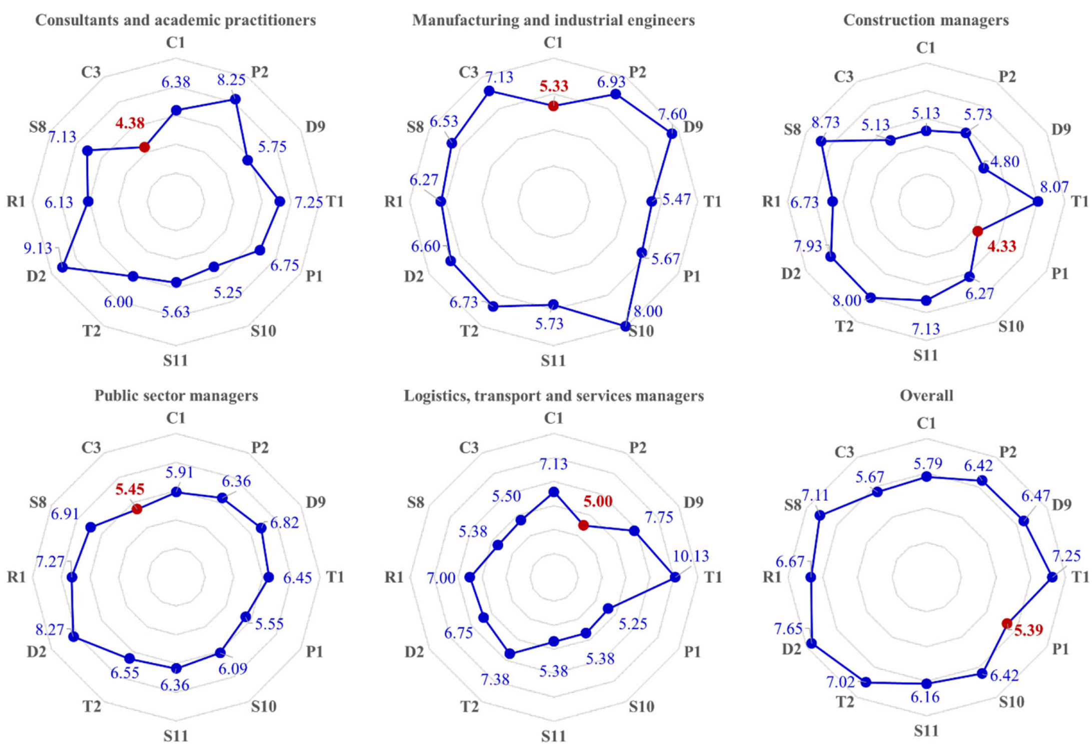


Figure 4 Comparison of average ratings for critical indices among SCM practitioners



4.3.2 Factors shaping perception: the three critical Cs

In terms of the factors that shape perceptions, the analysed critical indices reveal three critical C themes that underpin questions surrounding the critical indices of supply chain uncertainty. The three critical Cs are cost, context and customer, as shown in Figure 5. Interestingly, changes and delays are the two main terms that reflect the nature of these uncertainty-related themes in the critical indices. Changes concern P2, D9, T1, P1, T2 and D2, whereas delays relate to C1, C3, S10, S11, R1 and S8.

Cost-related perceptions concern potential changes due to costs associates with projects (P1), keeping up with technology (T2), and unexpected orders or demands (D2 and D9). In this context, perceived uncertainty relies on visible and reliable cost-effectiveness measures adopted within the supply chain. Confidence levels of SCM practitioners for costs also stem from credible and effective forecasts in estimates (Erkoyuncu *et al.*, 2013). These estimates may in turn influences degrees of uncertainty in virtuous (or vicious) circles concerning on-going and prospective expenditures for product development, production, service and disposal of equipment. Cost controls become imperative for supply chain planning and regulations that to curb regional and organisational expenditure within both public and private sectors whilst remaining competitive. This imperative is in part due to ramifications from projects cost overruns (e.g. from disruptive and unpleasant claims), high production costs (e.g. from damaged parts or equipment) and so on.

Conformance-related perceptions characterise changes and delays surrounding the fulfilment of customer requirements by

Figure 5 The three critical Cs (cost, conformance and connection) shaping uncertainty perception

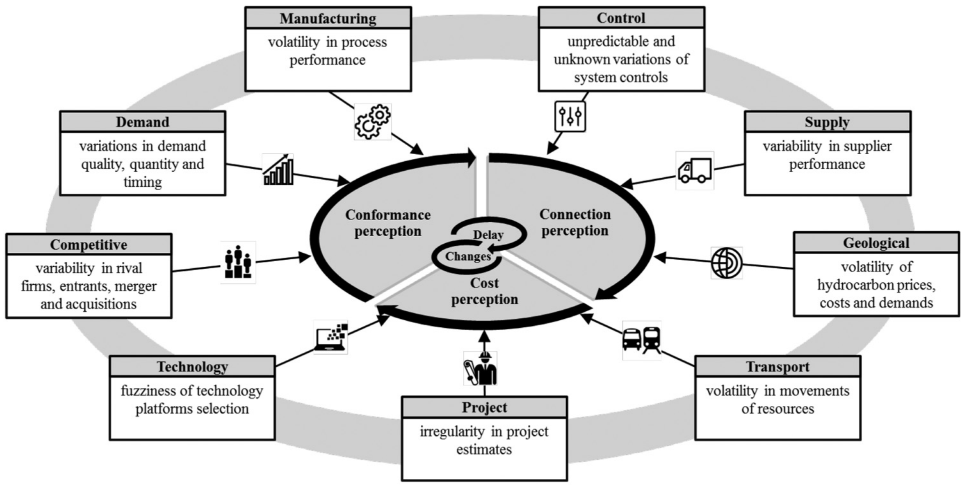
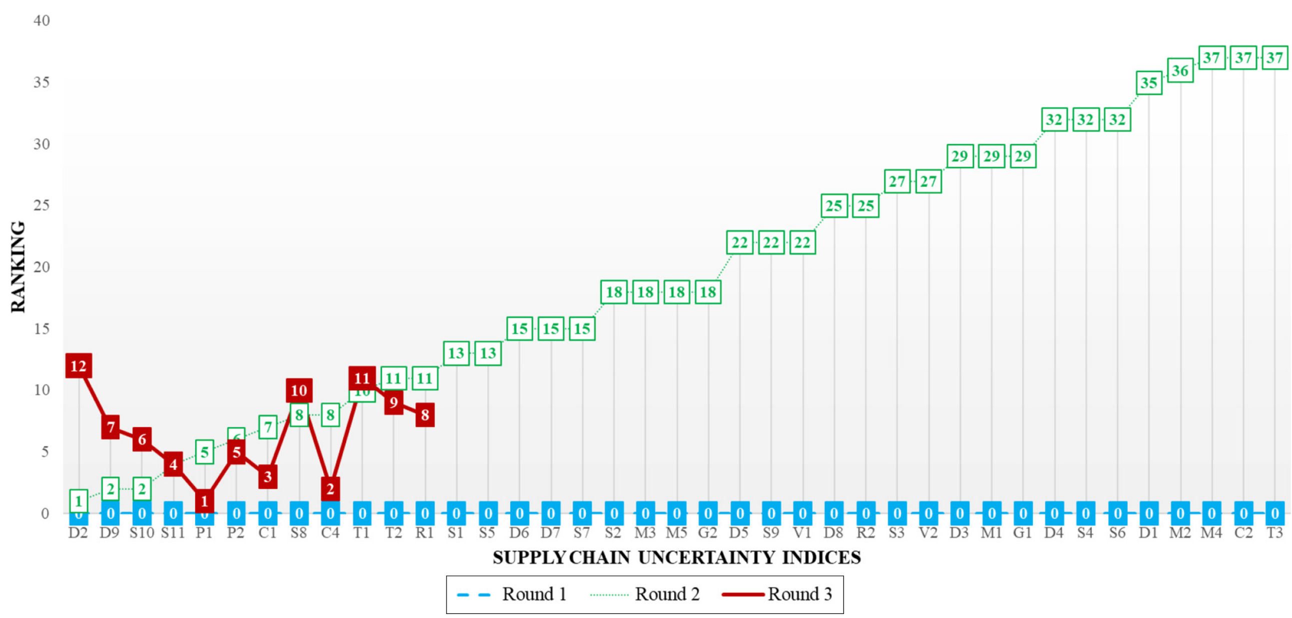


Figure 6 Overview of rankings for uncertainty indices during the Delphi rounds



supply chains in relation to materials (S10 and S11), orders (S8) and quality (P2). In this respect, perceived uncertainty hinges on confidence levels for high quality and timely delivery by supply chains. In supply chains, confidence levels underpin the orchestration that aids practitioners in enhancing operational performance. This leads to decisiveness for regional supply chains that are agile, i.e. respond to short-term changes in demand or supply quickly and handle external disruptions smoothly; adaptable, i.e. adjust their strategies, products, and technologies to meet structural shifts in markets; and aligned, i.e. bring into line the interests of all partners (Al-Shboul, 2017) – the so called "Triple-A" supply chain paradigm.

Connection-related perceptions apply to changes in platforms, systems and applications concerning information use (C1 and C3), updated technology (T1) and infrastructure availability (R1). Here, the perceived uncertainty depends on accuracy, availability and transparency that facilitates resource use in information environments for supply chains. These environments dictate governance as regions face an optimisation problem of maximizing their welfare while minimising barriers to business environments for investors (Maddah *et al.*, 2014). Regular updates and evolution in platforms, systems and applications are specifically significant for the increasing "vertical to virtual integration" trend in supply chains. For instance, the computer integrated manufacturing concept that was called material requirements planning in the 1970s, evolved into the manufacturing resource planning in the 1980s, and enterprise resource planning (ERP) in the 1990, and more recently in manifestations of cloud technology, Big Data systems and so on. Connection-related perceptions also in part explains progression pathways for supply chains in updates that transition from individualistic and independent governance (e.g. insurance, establishing supplier service levels, information sharing, relationship development, agreed performance standards, regular joint reviews) to more relational and collaborative governance (e.g. sharing strategic information, relationship development, joint training and development programmes, joint pro-active assessment and planning exercises, developing awareness and skills, joint strategies, inter-partnership structures and relationship marketing initiatives).

5. Discussion

Driven by supply chain uncertainty due to the evolving nature of operations strategy, the analysis and findings of this research shed light on the key questions that make SCM an onerous and obstinate function. Two main questions motivated this research:

RQ1. What are the critical indices of supply chain uncertainty in international operations?

RQ2. How do regional SCM practitioners perceive uncertainty in supply chains?

A three-round Delphi-based study explores how GCC-based SCM practitioners identify perceived indices of uncertainty and analyses how SCM practitioners perceive uncertainty. This section outlines the theoretical contributions and managerial implications of this research.

5.1 Theoretical contributions

This research makes two main theoretical contributions to SCM literature. First, it uses the unique context of the developing GCC region to reinforce the theoretical discourse on a holistic model of supply chain uncertainty. The research particularly highlights and accentuates the importance of potential variability, volatility and vulnerability of project, geological and transport sources due to focus on GCC supply chains. These sources reflect the significance of the region's oil and natural gas supply chains and the on-going major infrastructure projects that target economic diversification. The research also captures supply chain uncertainty originating from conventional sources that include unpredictable variations in *demand* or inaccurate forecasts, *supplier* performance variability, unreliable production *processes*, *competition* variability, unpredictability in *control* systems and variations due to the pace of *technological* innovation. Insights from the final round of the Delphi study show relatively high emphasis by managers, engineers and researchers on project uncertainty in term of changes to the cost of projects (P1) compared to the other uncertainty indices, as shown in Figure 6. This finding is in line with existing studies (Kreye *et al.*, 2012; Perminova *et al.*, 2008) suggesting that project work plays a significant role in the uncertainty perceived by managers and that variability in actual costs is highly problematic in a situation that is further exacerbated if unanticipated events occur. The findings are also consistent with the results of Flyvbjerg and Budzier (2011) who studied 1,471 projects and found an average cost overrun of 27%. Thus, an obvious aspect of uncertainty from projects involving regional supply chain is estimates of potential variability in relation to performance measures like cost, duration or quality related to particular planned activities. Hence, uncertainty is an unavoidable corollary to change projects. The findings also suggest supply chain experts prioritised control uncertainty in terms of information availability and transparency (C3) and information accuracy (C1). This result is in keeping with information processing theory which suggests that organisations need information to cope with environmental uncertainty that impacts other uncertainty sources and indices, e.g. changing customer demand, unstable suppliers, unpredictable actions of competitors and the complexity of inter-organisational activities in the supply chain (Busse *et al.*, 2017; Wong *et al.*, 2015).

Second, the research advances two theorisations on the process and factor associated with uncertainty perception. Thematic analysis of the steps and polling from this research shows an aggregative-accumulative duality concerning the manner of perception and the cost-conformance-connection triadic factors underlying the perceived critical indices. Using the Delphi study of this research as an example, the suggestion is that the proposed models may produce different critical indices. From an accumulative-based perspective, the top three or critical indices originate from demand and supply sources, whereas the critical indices from the aggregative-based perspective stem from project and control sources. The study shows that the main factors surrounding these critical indices from the aggregation process are rooted in perceptions of costs in relation to how the supply chain adopts cost-effectiveness measures and cost controls. Other factors from the thematic analysis are perceptions of conformance based on confidence levels for high quality and timely delivery, and perceptions of connections dependent on accuracy, availability and transparency for resource use. Beginning with a set of 39 indices based on literature and pilot study, the research relatively assesses and prioritise 12 critical indices. The expectation is that nature and relative impact of this disparity is an SCM challenge and opportunity for improving decision-making and responses to uncertainty. In a closely related study, Koh and Gunasekaran (2006) assess the relative impact of uncertainty at strategic, tactical and operational using 66 indices. However, this research focuses on insights from relative perceptions of uncertainty based on the orientation and mentalisation processes of SCM practitioners from the GCC region.

5.2 Managerial implications

This research also has two main managerial implications for SCM practitioners. First, this research has implications for supply chain strategy in terms of shedding light on high and low priority indices of uncertainty. Given the evolution in the industry and the challenges it faces, SCM for efficiency and effectiveness has become an attractive topic for both researchers and practitioners (Borodin *et al.*, 2016). Uncertainty management is central to boosting supply chain efficiency because uncertainty can originate from a range of sources and the SCM challenge involves identifying critical indices or questions to inform strategies for improved coordination and information sharing. Surprisingly, and

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contrary to the expectations of the authors, experts placed a low priority on indices from competitive, geological and manufacturing uncertainty sources. Possible explanations could be that the exogenous sources (i.e. geological and competitive uncertainty) for this regional supply chain possess salient features with increasing predictability or that the endogenous source (i.e. manufacturing uncertainty) has become latent to SCM and embedded in a strictly controlled process and planning for resources. Nonetheless, it is worth noting that these sources of uncertainty may have different roles in SCM or uncertainty perception may vary for different regional supply chains. For instance, previous studies show that competitive uncertainty has a moderating influence on the relationship between technology use in the supply chain and supply chain performance (Vijayasarathy, 2010) and that geological uncertainty has a significant impact on the actual performance of mine production systems and supply chains (Rahmanpour and Osanloo, 2016).

Second, the findings seem to suggest that the manner of joint evaluations for uncertainty influences strategic decisions if made collectively by SCM practitioners. This is because the integration of uncertain aspects plays a prominent role in managerial decision-making because it leads to potential increases in efficiency, responsiveness, business integration and market competitiveness. Furthermore, uncertainty constitutes the central problem confronted by any organisation, and it is for this reason that uncertainty and managerial action are inextricably linked (Townsend *et al.*, 2018). This underscores the importance of capturing the range of uncertainty sources and potential critical indices associated with different work environments and settings. The empirical enquiry of this research centres on the GCC region where the imperatives for regional supply chain involvement in global markets stems from both firm- and national-level pressures. The research findings suggest that the critical indices of supply chain uncertainty perceived by experts originate from projects and programmes (P1 and P2), control and planning (C1 and C3), supply and delivery (S8, S10 and S11), demand and distribution (D2 and D9), transport and logistics (R1), and technology and platforms (T1 and T2). As suggested earlier, the GCC region is characterised by the interplay of unique economic, political, governmental, geographical, technical, social and cultural attributes. From an SCM perspective, there are on-going developments in the region with grand plans to diversify GCC economies through state-level economic incentives and foreign direct investment in areas such as manufacturing, tourism, agriculture and so on. Consequently, considerations for these different factors in all likelihood will have implications for managers of supply chains with paths along the GCC region and for major firms with intentions of moving or outsourcing their operations to the GCC region.

6. Conclusions

According to Martin Luther King Jr, "you don't have to see the whole staircase; just take the first step". This quote epitomises the nature of uncertainty that pervades every fabric of life for individuals and organisations, and how uncertainty poses decision-making challenges due to lack of information or limited understanding of available information. For SCM practitioners, uncertainty stems from variability, volatility and vulnerability due to demand, supply, process, control, technology, competitive, project, geological and transport sources. The potential for a plethora of indices from these different sources makes it imperative that the critical indices of uncertainty are ascertained and ranked. In this research, a three-round Delphi study with seventy experts from the Sultanate of Oman in the GCC region aims to identify the critical indices of uncertainty for regional supply chains and analyse how SCM practitioners perceive uncertainty.

This study suggests that uncertainty perception depends on how supply chain experts aggregate or accumulate identified sets of indices. In other words, the relative significance of different uncertainty indices is dependent on variants in the mentalisation or orientation process for assemblage or successive factoring used by practitioners. The findings from the Delphi study in the GCC region show that when perceived as an accumulation, demand and supply sources critically perturb supply chain uncertainty. Here, the key questions (critical indices) that pose supply chain uncertainty are "Will the product demand be unexpected?", "Are there likely to be changes in customer orders?" and "What will be the pressure for on-time delivery?" These questions are associated with variability in supplier performance and distribution variations due to unpredictability of demand. However, when experts perceive supply chain uncertainty as an aggregation, project and control sources critically plague uncertainty. In this scenario, the key questions triggering supply chain uncertainty are:

- Are there likely to be changes to the cost of projects?
- Will information be available and transparent?
- Is available information transparent?

Here, the main concern is variability in planning for system controls and irregularity in programs for delivering projects. The study also suggests that these critical indices of supply chain uncertainty from the aggregation process stem from perceptions cost-, conformance- and connection-related factors. Perceptions of costs consider cost-effectiveness measures and cost controls, perceptions of conformance involve confidence in high quality and timely delivery, and perceptions of connections depend on accuracy, availability and transparency for resource use.

Theoretically, the research contributes to a holistic view of supply chain uncertainty as determined by disparate sources. It offers a unique insight based on the GCC region and identifying key uncertainty indices. The research also theorises on accumulative and aggregative uncertainty perception as two potential orientation-related and mentalisation-related processes for examining the relative significance of uncertainty indices. Practically, the findings have implications for supply chain strategy in regard to the assessment and prioritisation of supply chain uncertainty that should also involve project, geological and transport sources. The implications of the research findings also extend to strategic decision-making because it encourages firms to conduct multi-stage uncertainty assessments to inform resource planning and integration.

Some panel- and consensus-related limitations require carefully considered in relation to the impact and implications of this research. Panel limitations relate to the single focus on the Sultanate of Oman for assembling the Delphi panel while the consensus limitations relate to low consensus among the panel during the prioritisation round of the Delphi study notwithstanding the statistically significant ratings for indices provided by panel experts.

In spite of these limitations, the analysis and insights from this research provide a useful perspective on the prioritisation of uncertainty that informs designs of information environments required for enhanced decision making in the supply chain. With this in mind, future research will focus on the disparity between the aggregate and accumulate views on perceived supply chain uncertainty and avenues to integrate both views for a holistic perspective on supply chain uncertainty perception. Further work will also consider using literature on other geographical regions to elucidate an all-inclusive model of uncertainty perception and to examine other possible theorisations of collective uncertainty perception by supply chain experts. The expectation is that these future directions will consolidate the findings of this research and offer new theorisations and rationalisations that enhance regional and global SCM.

Overall, this research encourages mindsets for SCM that keep in step with contemporary challenges for operations which pose supply chain uncertainty; step up to prioritise uncertainty indices with attention paid to the nuances and niceties of regions involved in the supply chain and take steps to effectively manage supply chain uncertainty for virtuous circles involving effective supply chain strategy (re)formulation and implementation of technical solutions.

Note

1 Challenges for SCM include designing and delivering for value, sustainability, agility, adaptability, supportability, excellence, resilience, intelligence and integration (Brinch *et al.* 2018; Chand *et al.* 2015; Durugbo 2020; Gallear *et al.* 2014; Lummus *et al.* 2005; Luo *et al.* 2018; Prater *et al.* 2001; Reefke and Sundaram 2017, 2018; Seuring and Müller 2008; Wong *et al.* 2015).

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