Defence Research and Development Canada | Recherche et développement pour la défense Canada

CAN UNCLASSIFIED

Military supply chain flexibility measures

Abderrahmane Sokri
DRDC – Centre for Operational Research and Analysis

Journal of Modelling in Management
Vol. 9 No. 1, 2014, pp. 78-86
DOI 10.1108/JM2-10-2011-0050

Date of Publication from Ext Publisher: March 2014

Defence Research and Development Canada

External Literature (P)
DRDC-RDDC-2018-P010
February 2018

Canada

IMPORTANT INFORMATIVE STATEMENTS

Military supply chain flexibility measures

Abderrahmane Sokri
Defence Economics Team, DRDC CORA, Ottawa, Canada

Received 18 February 2011
Revised 24 October 2011
17 June 2012
Accepted 4 February 2013

Abstract

Purpose – So far, the author lacks a comprehensive definition of military supply chain (SC) flexibility, as well as performance measures to evaluate it. This paper aims to address these gaps. It seeks to develop performance measures to assess the flexibility of a military SC.

Design/methodology/approach – Volume flexibility is measured as the coefficient of variation of the demand quantity. Delivery side is measured in two stages using two ratios: customer satisfaction ratio and delivery flexibility ratio.

Findings – Building on the flexibility literature, novel performance measures were developed to assess the volume flexibility (the ability to change the level of moved products) and delivery flexibility (the ability to meet short lead times).

Research limitations/implications – This study characterizes the behaviour of a military SC by focusing on the volume and delivery sides. Efficiency, for example, is not within the scope of this analysis.

Practical implications – The results of this paper could serve as a means to compare between SCs with drastically different sizes.

Originality/value – This paper presents a novel ways to examine the flexibility of a military distribution process. The developed measures of flexibility are relevant, simple, dimensionless, and action-oriented.

Keywords Measurement, Supply chain management, Operations management, Modelling

Paper type Technical paper

1. Introduction

Supply chain (SC) logistics planning is a complex process in both military and civilian operations (Ganapathy *et al.*, 2003). This network involves multiple organizations and activities, including procurement and distribution (Leiphart, 2001). Procurement consists of buying materiel and ensuring that stocks on hand can meet demands. The distribution process involves activities related to the physical movement of goods between different geographic points. It integrates all logistics activities so that goods are distributed in the right quantities, to the right place, at the right moment, and at minimal cost.

The military SC is not totally dissimilar to other commercial SCs. On a basic level, both can be considered as three levels between producer, distributor and retailer or end-user. However, there are important differences that limit the application of commercial principles to military SC. Military SC exhibits high complexity, regulatory oversight, diverse customer requirements, heterogeneous supplier capabilities, and long life cycles. A customer in the military SC is the end-user that actually uses the moved product.

The primary objective of military SC is to attain a specific state of readiness at the lowest possible overall cost. The metric for military SC success is readiness for war, not profit gain (Burns *et al.*, 2010). Some commercial concepts such as just-in-time (holding less or no inventory) are no longer valid in the military area. In military supply,

Journal of Modelling in Management
Vol. 9 No. 1, 2014
pp. 78-86

1746-5664
DOI 10.1108/JM2-10-2011-0050

keeping massive inventory is a more adequate practice: a stock-out in military SC could engender a very high cost in case of war, for example. Compared to commercial SC where demand is relatively stable and products are shipped to a fixed network of stores, military demand is often variable and unpredictable (Wang, 2000). Conflict can arise anywhere at any time and the demanders in theatre are moving points.

One more important difference is that in commercial SC the flow of products is unidirectional between suppliers and retailers. In military SC, the flow between suppliers and end-users is bidirectional mostly because of preventive and corrective maintenance of equipment. Furthermore, the military's supply consists of a large number of very different types of items, ranging from everyday supplies to specific military equipment, which requires particular transportation and packaging techniques.

In many countries across the world, military distribution systems still have many shortcomings that may threaten their global reach. The overall end-user satisfaction is relatively low. In Canada, for instance, the May 2008 report of the Auditor General of Canada (AGC, 2008) identified an important weakness in the SC performance measurement. The AGC has also reviewed the audit reports for the supply operations of the USA and British forces and they show problems similar to those experienced by the Canadian forces (AGC, 2008). During the Gulf War (1990-1991), for example, the ports of embarkation and debarkation were overcrowded with supplies that had to be processed and moved to direct support locations. This distribution problem was due to a lack of equipment needed for deployment (Leiphart, 2001).

Key performance indicators (KPIs) or key success indicators are ways to periodically assess the performances of organizations. KPIs could be used by military SCs to evaluate their success. Flexibility is one of the KPIs that should be established to monitor the responsiveness of a SC. SC flexibility is defined as the ability of the SC to respond to the changing requirements of purchased components in terms of volume and delivery date (Tachizawa and Gimenez, 2010). Flexibility is an important characteristic of a high-performance SC (Beamon, 1999). It provides an effective parameter for characterizing the behaviour of a SC (Das and Abdel-Malek, 2003). This KPI plays an important role both in military and civilian operations.

In many industries, for example, SC flexibility has been considered as a major determinant of competitiveness between private firms (Pujawan, 2004) and for gaining competitive advantages (Winkler, 2009). In both sectors, managing flexibility in SCs involves a variety of actions that are related to various financial factors (More and Babu, 2009).

Building on the flexibility literature, new performance measures of flexibility were developed in this paper. In particular, the analysis addresses the following research questions:

RQ1. What aspects of flexibility should be measured in a military SC?

RQ2. How can the measures be used to evaluate the overall flexibility of a military SC system?

This paper is organized into six sections. Following the introduction, Section 2 provides a comprehensive review of literature on SC flexibility. Section 3 defines the military SC flexibility and develops performance measures to assess it. Section 4 characterizes the performance measures. Section 5 explores new avenues for future research. The paper concludes in Section 6.

2. Literature review

A good military SC is willing to accommodate the uncertainties and variations in volume and delivery. This study presents a novel way to examine the flexibility of a military distribution process. This concept is important because of the instability and unpredictability of the environment in which the SCs operate (Slack, 1983). A growing body of literature has begun to recognize that in the era of SC management it is important to look to the flexible SC (Stevenson and Spring, 2007). For the purposes of this analysis, some recent literature highlights the importance of flexibility in military SCs. A comprehensive review of the available literature on this topic can be found in Stevenson and Spring (2007).

Reichhart and Holweg (2007), for example, synthesised the existing contributions to manufacturing and SC flexibility and responsiveness. They identified four types of flexibility: product, volume, mix and delivery. Beamon (1999) presented an overview and evaluation of the performance measures used in SC models. The author indicated that the SC performance measurement system must contain at least one of the three types of performance measures identified as necessary components in any SC performance measurement system: resource measures, output measures, and flexibility measures. More and Babu (2009) assessed the influence that may be exerted by various types of SC flexibilities on the management ratios. The authors found that it was difficult to establish generalized relationships between these two sets of entities. Sánchez and Pérez (2005) used correlation coefficients to analyze the relationship between the dimensions of SC flexibility and firm performance in a sample of Spanish automotive suppliers. Manders (2009) conducted a cross sectional study to determine the impact of SC flexibility on customer satisfaction. The results indicate that there is a positive relationship between flexibility and customer satisfaction. Lummus *et al.* (2003) developed a framework on SC flexibility. They specified the components of SC flexibility and potential characteristics of each component that result in a flexible SC. The authors showed in particular that increased SC flexibility would be positively related to reductions in SC inventory in terms of inventory value.

Pujawan (2004) presented a general guideline for conducting flexibility assessment of a SC. The author identified four main parts of flexibility including flexibility of the product delivery system, production system, product development, and supply system. Kumar *et al.* (2008) classified the flexibility enablers as strategic, operational and performance-based enablers. They observed that some enablers having high-driving power and low dependency are of strategic importance. These enablers require more attention while other enablers based on operations and performance are dependent of strategic enablers. Tachizawa and Gimenez (2010) conducted a survey among Spanish purchasing professionals to analyze how different sourcing practices are combined to form particular supply flexibility strategies. The results show that Spanish firms have no single approach to achieve supply flexibility and that the type of flexibility achieved depends on the strategy followed (integrated, domestic or offshore). Barad and Sapir (2003) used a customer oriented logistic performance measure to examine potential benefits of flexibility in logistic systems. They quantitatively investigated the capability to quickly transfer parts between locations referred to as trans-routing flexibility. Winkler (2009) identified resources, objects and parameters of SC flexibility. He demonstrated how to manage the structural, technological and human potentials of the strategic SC network to gain outstanding SC flexibility. Akgün and Tansel (2007) studied

the physical movement of military units, stationed at geographically dispersed locations, from their home bases to their designated destinations. Their model could be used to plan and execute cost-effective deployment operations at different levels of planning.

More recently, Schütz and Tomasgard (2011) analyzed the effects of volume flexibility, delivery flexibility and operational decision flexibility in operational SC planning under uncertain demand. Their results show that, given sufficient flexibility in the SC, a deterministic approach to SC planning may result in equally good (or better) results as a stochastic planning. Gosling *et al.* (2010) examined how buying organisations can configure their supply networks to achieve SC flexibility. They argued that an agile and flexible SC is a way of coping with the high levels of uncertainty. Das (2011) developed a model for capacity, distribution and input supply flexibility. The author integrated them to improve market responsiveness and address demand and supply uncertainty.

While the performance measures developed in this paper aim primarily to assess the flexibility of a military SC, these indicators may also be used in non-military organizations to improve their strategic market responsiveness. At the strategic level, these indicators could be used as proactive attributes rather than a reactive evaluation. They could, for example, be integrated into the strategic partnering model to select flexible suppliers and inform sourcing and procurement decisions, as described in Gosling *et al.* (2010). They could also help in forecasting the new capacity to be acquired to offset an anticipated percentage of demand increase, as described by Das (2011).

3. Measuring the SC flexibility

Flexibility is vital to the success of the military SC. Slack (1991) identifies two types of flexibility: response (or delivery) flexibility and range (or volume) flexibility. Many authors showed that deficiencies in these two types of flexibility are most often the cause of customer-supplier grievance (Das and Abdel-Malek, 2003). A flexible SC system increases customer satisfaction by meeting short lead times (delivery flexibility) and handling wide ranges of quantities demanded (volume flexibility).

3.1 Volume flexibility

In military SC, each demand is characterized by a required delivery day (RDD) and a material priority code (MPC) attribute. The RDD indicates when the item is needed in theatre and the MPC specifies its degree of priority (e.g. operationally critical, essential, routine, replenishment). These attributes are used to determine how requisitions and demand objects are treated in the SC. For example, high priority demand objects with low RDD values would travel to theatre via air, whereas low priority items with longer RDD values would likely travel via maritime means. To ensure that demands are resourcefully fulfilled, a good military SC should be willing to accommodate the variations in volume. Volume flexibility could therefore be defined as to what extent the demand quantity can be changed. A SC is consequently volume flexible if it can respond to and accommodate large demand variations.

To compute the volume flexibility of a SC, let q_{pt} (in pallets, containers or tonnes) be the demand quantity with MPC p ($p = 1,2,\ldots,m$) at time t ($t = 1,2,\ldots,T$). Let $s(q_p)$ be the standard deviation of the sample q_{pt} and $\bar{q}_p$ its mean. For the MPC p, the volume flexibility, VF_p, could be measured as the coefficient of variation of the sample q_{pt}. This coefficient is defined as the ratio of the standard deviation to the mean, and is calculated as follows:

$$VF_p = \frac{s(q_p)}{\bar{q}_p}. \tag{1}$$

The standard deviation is a measurement of variability. It measures the dispersion of data around the mean. It is low when the data points tend to be very close to the mean and high when data are spread-out and widely dispersed. Unlike variance, the standard deviation has the useful characteristic to be expressed in the same unit as the data. The coefficient of variation provides a relative measure of data dispersion with respect to the mean. It is small when the data scatter compared to the mean is small and large when the variation is important. This statistic is a useful diagnostic term. Since this relative measure has no unit, it is very useful when comparing the amount of variation among groups with different means or units. Used as a relative measure of flexibility, it indicates whether there are a large or small number of undersized or outsized demand quantities. A large coefficient of variation indicates that the SC is able to adapt adequately to large variations in demand.

3.2 Delivery flexibility

Modeling the flexibility of lead-times in SCs has retained its position as an important topic in maintaining operational readiness of military personnel (Wang, 2000). Delivery flexibility could be defined as the ability to meet short lead times. Consider the item i ($i = 1,2,\ldots,n$) with degree of priority p. Let D_{ip} be its RDD and R_{ip} its response time. The response is defined as the amount of time between the placing of an order, $T_0(ip)$, and the time at which the item is received, $T_f(ip)$, that is, $R_{ip} = T_f(ip) - T_0(ip)$. Consider the following indicator function defined as:

$$f_p(i) = \begin{cases} 1, & if \ \ \mathrm{T_f(ip)} \le D_{ip}, \\ 0, & otherwise. \end{cases} \tag{2}$$

Delivery flexibility for items with priority p could be measured in two stages using two ratios.

In stage 1, for the MPC p, the first indicator of delivery flexibility, DF_p^1, is calculated as follows:

$$DF_p^1 = \frac{1}{n}\sum_{i=1}^{n} f_p(i). \tag{3}$$

This first ratio belongs to the unit interval and determines the proportion of items completed within a given reporting period. It indicates how well the SC is meeting the final customer's required delivery date: the higher DF_p^1, the higher the end-user satisfaction, and the higher the delivery flexibility of the military SC.

In stage 2, consider the response time of the l items meeting the RDD ($T_f(jp) \le D_{jp}, 1 \le j \le l \le n$) and the corresponding average RDD:

$$\bar{D}_p = \frac{1}{l}\sum_{j=1}^{l} D_{jp}. \tag{4}$$

For each item j meeting the RDD, define the positive variation of saved time as:

$$\delta_{jp} = D_{jp} - \mathrm{T_f(jp)} \tag{5}$$

A second relative measure of delivery flexibility, DF_p^2, is given by the following ratio:

$$DF_p^2 = \frac{\bar{\delta}}{\bar{D}_p} \tag{6}$$

This measure is defined as the ratio between the average δ_{jp} and the average RDD. A ratio larger than zero means that the SC has a given degree of leeway to deliver some items before their RDDs.

4. KPIs characteristics

The three developed metrics $\left(VF_p, DF_p^1 \text{ and } DF_p^2\right)$ have a clear purpose: to quantify the flexibility of a military SC. They would help military forces learn lessons from their old experiences and incorporate those lessons into their future operational planning. As it can be seen, these ratios are relevant, simple, easy to use, and action-oriented. They present the most desirable characteristics of a KPI, which are measurability, inclusiveness, universality, and consistency (Beamon, 1999).

Measurability

These ratios are based on quantitative data and expressed numerically. They could be statistically analyzed or represented visually in graphs and tables. This type of data allows managers to describe trends and base their decisions on something enumerated. Since q_{pt} is a strictly positive measure, the ratio in equation (1) coincides also with the relative standard deviations.

Universality

The universality is the ability of a KPI to be applied under various operating conditions. These KPIs are indeed broad enough to be useful for any military SCs at any time or place. They could assess both long-term and short-term flexibility performance.

These measures of flexibility present two important advantages:

(1) they are dimensionless numbers; and

(2) they could be expressed as percentage (in which case they are multiplied by 100 percent).

Therefore, the ratios in equations (1) and (6) $\left(VF_p \text{ and } DF_p^2\right)$ are largely preferred to other measures of variation such as variance or standard deviation, because they can compare between SCs with different units or widely different means. The metric VF_p may be directly applied to measure the volume flexibility of a commercial SC. To use the delivery flexibility metrics $\left(DF_p^1 \text{ and } DF_p^2\right)$ in a commercial SC, the end-users should be replaced by retailers.

Inclusiveness

These ratios take within their scope the most pertinent aspects of SC processes. They provide a comprehensive view of performance and include the whole logistics process from end-to-end.

Consistency

Consistency refers to alignment with organization goals. These KPI are concurrent with the military strategy. They reinforce the military strategy by assigning accountability for achieving results and improving processes.

5. Future research

A military SC is a network of military and non-military organizations that, through their activities, perform logistic functions in order to efficiently fulfill the demands of the operational commands in theatre. The majority of supply items that a soldier needs such as ammunition, rations, water, and medical supplies, come through this chain. It spans from its vendors to the theatre of operations, moving several products daily, and keeping them in inventory for various needs (Berger *et al.*, 2008). Its main objective is to ensure that customer demands are efficiently fulfilled using a flexible system.

This study characterizes the behaviour of a military SC by focusing on the volume and delivery sides. Following this study, further analysis should be conducted to address other issues associated with the SC flexibility. Efficiency, for example, is a central issue for distribution chain success. SC is not only constrained by time and quantity, but by budget as well. Overemphasis on one constraint will be at the expense of the others. A successful SC must meet, on time, the end-user requirements within its allocated budget. Therefore, a natural extension to this study is to consider a multi-objective time-cost-volume trade-off analysis to search for the most useful resource utilization. The solution(s) should minimize delivery time and cost while ensuring a given degree of volume flexibility.

6. Conclusion

Military SC is usually handled by both military and commercial logistics providers. Due to its hybrid nature (civilian – military), it is therefore necessary to develop standardized performance measurement mechanisms to which each community can agree. Flexibility is an important characteristic of a high-performance SC as it indicates the ability of the SC to respond in a timely and cost-effective manner to any change in the end-user demands and delivery dates. The main measures of SC flexibility are the volume flexibility and the delivery flexibility. Volume flexibility refers to varying order quantities, whereas the delivery flexibility is related to shortening supply lead-times.

This paper seeks to further the understanding of military SC flexibility and provides three metrics to assess it. The three developed metrics are relevant, simple, easy to use, and action-oriented. They present the most desirable characteristics of a KPI, which are measurability, inclusiveness, universality, and consistency.

Further research could be conducted to address other questions associated with the military SC flexibility. A natural extension to this analysis is to consider a multi-objective time-cost-volume trade-off analysis to optimize resource utilization.

References

Akgün, I. and Tansel, B. (2007), "Optimization of transportation requirements in the deployment of military units", *Computers & Operations Research*, Vol. 34 No. 4, pp. 1158-1176.

(The) Auditor General of Canada (2008), "Support for overseas deployments-national defence", Report No. FA1-2008/1-2E, 38.

Barad, M. and Sapir, D. (2003), "Flexibility in logistic systems modeling and performance evaluation", *International Journal of Production Economics*, Vol. 85 No. 2, pp. 155-170.

Beamon, B.M. (1999), "Measuring supply chain performance", *International Journal of Operations & Production Management*, Vol. 19 No. 3, pp. 275-292.

Berger, J., Boukhtouta, A., Chouinard, M., Ghanmi, A., Girard, S., Guitouni, A. and Martel, A. (2008), "Canadian forces supply network: strategic need and design methodology", Working Paper, CIRRELT Report 2008-34, Laval University, Québec, p. 36.

Burns, L., Tseng, F. and Berkowitz, D. (2010), "Global network analysis in a military supply chain: using a systems based approach to develop a next-generation end-to-end supply chain performance measurement and prediction system", *Proceedings of the 2010 Cambridge International Manufacturing Symposium, Cambridge, UK, 23-24 September*, p. 12.

Das, K. (2011), "Integrating effective flexibility measures into a strategic supply chain planning model", *European Journal of Operational Research*, Vol. 211 No. 1, pp. 170-183.

Das, S.K. and Abdel-Malek, L. (2003), "Modeling the flexibility of order quantities and lead-times in supply chains", *International Journal of Production Economics*, Vol. 85 No. 2, pp. 171-181.

Ganapathy, S., Narayanan, S. and Srinivasan, K. (2003), "Simulation based decision support for supply chain logistics", *Proceedings of the 2003 Winter Simulation Conference, New Orleans, LA, 7-10 December*, pp. 1013-1020.

Gosling, J., Purvis, L. and Naim, M. (2010), "Supply chain flexibility as a determinant of supplier selection", *International Journal of Production Economics*, Vol. 128 No. 1, pp. 11-21.

Kumar, P., Shankar, R. and Yadav, S. (2008), "Flexibility in global supply chain: modeling the enablers", *Journal of Modelling in Management*, Vol. 3 No. 3, pp. 277-297.

Leiphart, K.L. (2001), "Creating a military supply chain management model", *Army Logistician*, Vol. 33 No. 4, pp. 25-31.

Lummus, R., Duclos, L. and Vokurka, R. (2003), "Supply chain flexibility: building a new model", *Global Journal of Flexible Systems Management*, Vol. 4 No. 4, pp. 1-13.

Manders, J. (2009), "Supply chain flexibility aspects and their impact on customer satisfaction", Master of Supply Chain Management, open university of The Netherlands, Heerlen.

More, D.S. and Babu, S. (2009), "Analysis of the dynamics between supply chain flexibility and key management ratios", *International Journal of Business Innovation and Research*, Vol. 3 No. 2, pp. 199-227.

Pujawan, I.N. (2004), "Assessing supply chain flexibility: a conceptual framework and case study", *International Journal of Integrated Supply Management*, Vol. 1 No. 1, pp. 79-97.

Reichhart, A. and Holweg, M. (2007), "Creating the customer-responsive supply chain: a reconciliation of concepts", *International Journal of Operations & Production Management*, Vol. 27 No. 1, pp. 1144-1172.

Sánchez, A.M. and Pérez, M.P. (2005), "Supply chain flexibility and firm performance: a conceptual model and empirical study in the automotive industry", *International Journal of Operations & Production Management*, Vol. 25 No. 7, pp. 681-700.

Schütz, P. and Tomasgard, A. (2011), "The impact of flexibility on operational supply chain planning", *International Journal of Production Economics*, Vol. 134 No. 2, pp. 300-311.

Slack, N. (1983), "Flexibility as a manufacturing objective", *International Journal of Operations & Production Management*, Vol. 3 No. 3, pp. 4-13.

Slack, N. (1991), *The Manufacturing Advantage*, Mercury Books, London.

Stevenson, M. and Spring, M. (2007), "Flexibility from a supply chain perspective: definition and review", *International Journal of Operations & Production Management*, Vol. 27 No. 7, pp. 685-713.

Tachizawa, E.M. and Gimenez, C. (2010), "Supply flexibility strategies in Spanish firms", *International Journal of Production Economics*, Vol. 124 No. 1, pp. 214-224.

Wang, M.Y.D. (2000), "Accelerate logistics: streamlining the army's supply chain", Technical Report, RAND Report MR-1140-A, p. 48.

Winkler, H. (2009), "How to improve supply chain flexibility using strategic supply chain networks", *Journal Logistics Research*, Vol. 1 No. 1, pp. 15-25.

About the author

Abderrahmane Sokri received a Master degree in applied economics and statistics from l'Institut National de Statistique et d'Économie Appliquée (INSEA, Morocco). He holds a Master degree in economics from l'Université de Montréal (UdeM) and a PhD in administration from HEC-Montréal. He served as a Statistician at la Banque Centrale Populaire (Morocco) and as an Economist at the Moroccan Department of Finance. He taught statistics, mathematics and economics for several years in many institutions of higher education including INSEA, UdeM and HEC-Montreal. He is currently an Economist with the Department of National Defence (Canada). His research interest includes statistics, operational research and differential games applied to defence economics and environmental management. Abderrahmane Sokri can be contacted at: Abderrahmane.Sokri@gerad.ca

DOCUMENT CONTROL DATA

(Security markings for the title, abstract and indexing annotation must be entered when the document is Classified or Designated)

1. ORIGINATOR (The name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g., Centre sponsoring a contractor's report, or tasking agency, are entered in Section 8.)

DRDC – Centre for Operational Research and Analysis
Defence Research and Development Canada
101 Colonel By Drive
Ottawa, Ontario K1A 0K2
Canada

2a. SECURITY MARKING (Overall security marking of the document including special supplemental markings if applicable.)

CAN UNCLASSIFIED

2b. CONTROLLED GOODS

NON-CONTROLLED GOODS
DMC A

3. TITLE (The complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title.)

Military supply chain flexibility measures

4. AUTHORS (last name, followed by initials – ranks, titles, etc., not to be used)

Sokri, A.

5. DATE OF PUBLICATION (Month and year of publication of document.)	6a. NO. OF PAGES (Total containing information, including Annexes, Appendices, etc.)	6b. NO. OF REFS (Total cited in document.)
March 2014	9	25

7. DESCRIPTIVE NOTES (The category of the document, e.g., technical report, technical note or memorandum. If appropriate, enter the type of report, e.g., interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

External Literature (P)

8. SPONSORING ACTIVITY (The name of the department project office or laboratory sponsoring the research and development – include address.)

DRDC – Centre for Operational Research and Analysis
Defence Research and Development Canada
101 Colonel By Drive
Ottawa, Ontario K1A 0K2
Canada

9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.)	9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.)

10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document.)	10b. OTHER DOCUMENT NO(s). (Any other numbers which may be assigned this document either by the originator or by the sponsor.)
DRDC-RDDC-2018-P010	

11a. FUTURE DISTRIBUTION (Any limitations on further dissemination of the document, other than those imposed by security classification.)

Public release

11b. FUTURE DISTRIBUTION OUTSIDE CANADA (Any limitations on further dissemination of the document, other than those imposed by security classification.)

12. ABSTRACT (A brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual.)

Purpose – So far, the author lacks a comprehensive definition of military supply chain (SC) flexibility, as well as performance measures to evaluate it. This paper aims to address these gaps. It seeks to develop performance measures to assess the flexibility of a military SC.
Design/methodology/approach – Volume flexibility is measured as the coefficient of variation of the demand quantity. Delivery side is measured in two stages using two ratios: customer satisfaction ratio and delivery flexibility ratio.
Findings – Building on the flexibility literature, novel performance measures were developed to assess the volume flexibility (the ability to change the level of moved products) and delivery flexibility (the ability to meet short lead times).
Research limitations/implications – This study characterizes the behaviour of a military SC by focusing on the volume and delivery sides. Efficiency, for example, is not within the scope of this analysis.
Practical implications – The results of this paper could serve as a means to compare between SCs with drastically different sizes.
Originality/value – This paper presents a novel ways to examine the flexibility of a military distribution process. The developed measures of flexibility are relevant, simple, dimensionless, and action-oriented.

13. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g., Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

Measurement, Supply chain management, Operations management, Modelling