How much visibility has a company over its supply chain? A diagnostic metric to assess supply chain visibility

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Abstract

In an interconnected and increasingly complex world, no supply chain is immune to disruptions. Managing supply chain visibility is being recognised by many researchers and practitioners as vital. In fact, visibility has been proven to reduce uncertainty and improve decision coordination, therefore increasing resilience. Still, quantifying the visibility remains a hard task for managers. This paper aims to describe an approach that, based on the types and properties of the shared information, allows managers to assess the degree of visibility over its supply chain partners. Our approach represents a first attempt to quantify the visibility necessary to deal with disruptions, taking into account a holistic view of the supply chain. The resulting metric represents the main contribution of this study. In particular, the metric should be used as diagnostic tool providing to decision-makers an overview of its supply chain in order for them to identify the nodes where improvement actions are more effective. Additionally, the metric can be used for benchmarking purposes. Main limitation of the study is related to the lack of a weight attribution for node differentiation. Future research will aim to differentiate the supply chain nodes in terms of their relevance but also to test the accuracy and practical usability of the metric in real context.

Keywords: Supply chain visibility, quantitative approach, visibility metric, decision-makings

1. Introduction

Nowadays, companies are called to operate in a context characterised by increasing complexity, growing adoption of outsourcing, global dispersion of partners, and continuous reduction of production costs. All these characteristics lead to growing uncertainty and consequently to a greater exposure to risks and disruptions of the supply chains. In such fast-changing context taking decisions effectively is imperative.

According to many researchers and practitioners a solution to this problem is represented by supply chain visibility (SCV) (Barratt and Barratt, 2011; Barratt and Oke, 2007; KPMG, 2016; KPMG, 2018; Zhang et al., 2011). SCV refers to the capability of supply chain players to have access to or to provide the required timely information from/to relevant supply chain partners for better decision support (Goh et al., 2009).

Although highly recommended, SCV appears difficult to achieve and decision-makers believe that this can be related to a lack of a common metric (McIntire, 2014; Somapa et al., 2018). At

this regards, several authors have attempted to provide qualitative and quantitative methods to assess visibility (Barratt and Barratt, 2011; Barratt and Oke, 2007; Brandon-jones et al., 2014; Caridi et al., 2010 b; Caridi et al., 2013; Lee and Rim, 2016; Kim et al., 2011; McIntire, 2014; Williams et al., 2013; Yu and Goh, 2014; Zhang et al., 2011) but most of them have focused their attention on dyadic relationships or linear supply chains, and so failing in grasp the real complexity of modern supply chain networks (Caridi et al., 2010).

Therefore, with this research we aim to describe a quantitative approach that, based on the types and properties of the shared information, allows managers to assess the degree of visibility of their supply chain partners. In particular, the resulting metric is intended to support decision-makers in benchmarking the visibility of different supply chain partners and in preparing for effective disruptions management in complex supply chains. This will enable us to answer the research question: "How to assess the visibility that a company has over its supply chain partners?"

The main contribution of the paper is represented by the SCV metric itself. The metric should provide the degree of visibility that a company, in any position within the supply chain, has over its internal, upstream and downstream partners, and also it allows decision-makers to identify the nodes where improvement actions are more effective.

The remainder of this paper is structured as follows: Section 2, reviews the literature related to supply chain visibility and its evaluation. Section 3 presents the research methods, while in Section 4 a characterisation of the dimensions under analysis and the approach that explain how to use the metric is proposed. Finally, Section 5 reflects on the presented research and discusses its implications for research and practice.

2. Supply chain visibility

Supply chain visibility has been a very welcomed topic both in information management and supply chain management streams of literature; still there is not consensus about its definition. Many authors approached visibility according to multiple perspectives (Messina et al., 2017), for example related to data and information management (Barratt and Barratt, 2011; Barratt and Oke, 2007; Brandon-Jones et al., 2014; Caridi et al., 2010 b; Caridi et al., 2013; Goh et al., 2009; Goswami et al., 2013; Tohamy et al., 2003; Williams et al., 2013), to supply chain partners' capability (Caridi et al., 2014; Griffiths et al., 2009; Kleuber and O'Keefe, 2013; Nooraie and Parast, 2015; Zhang et al., 2011), to supply chain configuration (Caridi et al., 2010 a), to the impact it has on business process (Barratt and Oke, 2007; Caridi et al., 2014; Kaipia and Hartiala, 2006; Lee and Rim, 2016; Kim et al., 2011; McIntire, 2014), and to event management (Francis, 2008; McCrea, 2005). This lack of consensus in defining supply chain visibility has had repercussions in terms of the absence of a univocal metric for its assessment.

Although the literature has shown some attempts to provide ways to assess SCV, by adopting both qualitative and quantitative methods, two approaches seem to stand out: the first deals with visibility by analysing the types and properties of the information shared (Barratt and Barratt,

2011; Caridi et al., 2010 b; Caridi et al., 2013; Griffiths et al., 2009; Williams et al., 2013; Zhang et al., 2011), while the second focuses on the impact that this exchange of information has on business performance (Barratt and Oke, 2007; Kaipia and Hartiala, 2006; Lee and Rim, 2016; McIntire, 2014).

In line with the first approach we are interested in analysing supply chain visibility by focusing on the characteristics of the information shared. In this regard the mathematical techniques adopted in works of Caridi et al. (2010 b) and Zhang et al., (2011), are considered the most objective in dealing with visibility assessment (Lee and Rim, 2016; Williams et al., 2013). Caridi et al., (2010 b) provide a quantitative model to assess node visibility in complex supply chains. They provide a metric to assess the quantity and the quality of four types of information, namely transactions, status information, master data, and operation plan (Caridi et al., 2010 b; Caridi et al., 2013; Caridi et al., 2014). To estimate the overall supply chain visibility, these authors consider two additional variables namely, one related to the distance between the node and the focal company, and another to the significance of the node for the focal company. On the other hand, the study of Zhang et al. (2011) proposes a metric to assess inventory visibility by analysing a company's capabilities to have access and to provide the available information about the inventory from/to supply chain partners.

Although we found these two studies to be the most objective in quantifying supply chain visibility, they are not without limitations. In fact, in spite of aiming at providing a global SCV measurement, the study of Caridi et al. (2010 b) ends up providing solely the assessment for the inbound supply chain. Zhang et al. (2011), on the other hand, considers solely the inventory information dimension, and only its quantity.

In order to overcome these limitations while maintaining the objectivity of the metric, we propose a model that supports decision-making in complex supply chains, based on the types and properties of the information shared among supply chain partners. In particular, we focus our attention on the types, accessibility, quantity, and quality of information shared (Barratt and Barratt, 2011; Caridi et al., 2010 b; Caridi et al., 2013; Williams et al., 2013; Zhang et al., 2011).

3. Research method

To develop the visibility metric, we structured the research in two phases. Taking into account that this study is theoretical in nature, the first phase involved the definition of the dimensions of the metric, and the mathematical model to assess them. This phase was based both on the literature review about visibility assessment and on several brainstorming sessions with the leading research group. In the second phase, we carried out a focus group (Krueger and Casey, 2009) with a panel of expert practitioners. The goal of the focus group was to test the practical relevance of the metric and to improve its usability. We believe this approach provides a good balance between theoretical rigor and practical relevance of the resulting metric.

4. A quantitative approach for supply chain visibility assessment

Supply chain management (SCM) involves the management of product, finance and information flows in a supply chain, as reported in Figure 1 (Mentzer et al., 2001). In particular, the product flows from upstream to downstream, money flows in the opposite direction, while information flows in both directions to synchronise the other two streams.
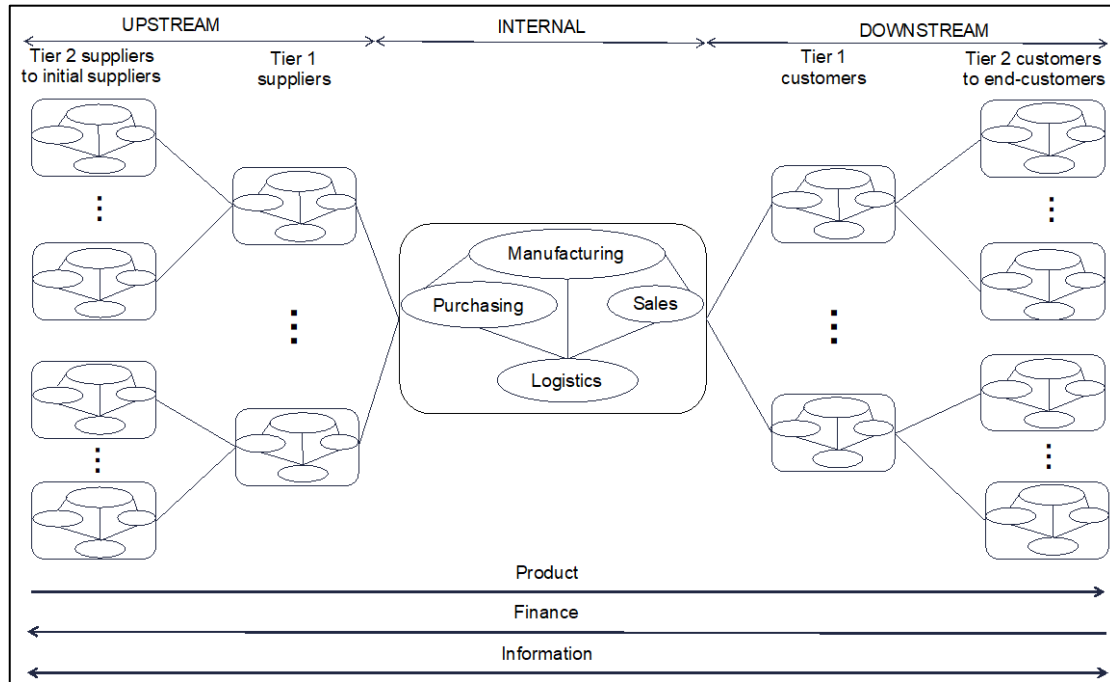

Figure 1 Supply chain network structure (Adapted from Lambert and Cooper, 2000)

In such complex networks, companies achieve supply chain visibility by considering both internal and external visibility. Internal visibility refers to the visibility that a firm has by sharing information directly with its internal functions, such as purchasing, manufacturing, sales, and logistics. On the other hand, we refer to external visibility as the visibility that a firm has over the information shared directly with both upstream and downstream partners.

Therefore, in order for decision-makers to have a global view of their supply chain, visibility over their internal functions, suppliers, and customers must be considered.

4.1. Dimensions of the model

In order to provide such global view of the supply chain, firms need to exchange different types of information across the supply chain. These types of information can be grouped into internal and external. Internal information is any information present at firm level or supply chain level gathered from companies' information systems, while external information refers

to any information related to supply chain or the environment, and gathered from institutional reports, stock market, public institutions, and consultancy reports, among others (Messina et al., 2017).

We refine such generic categories to increase their level of detail, and their interpretability by adopting terms used by managers in real contexts. Therefore, the **types of information (I)** representing the object of the analysis are the following:

1. **Available capacity:** capacity of equipment and manpower to execute extra work;

2. **Production process:** sequence of processes needed to make a product;

3. **Stock level:** level of available inventory in-house, in transit, and backlog;

4. **Order/supplier order/customer order:** refers to both confirmed order and communication of changes from/to the interested parties. For supplier and firm, it includes also forecasts;

5. **Geopolitical constrains:** geographical and political conditions where the partners are based that can affect the manufacture of the final product;

6. **Track and trace:** capability of a firm to track and trace the position of goods starting from the production until the delivery to the end customer;

7. **Logistics service provider contract:** contractual conditions agreed linking the firm and logistics service provider, such as carriers;

8. **Supplier/customer contract:** contractual conditions agreed between the firm and its supply chain partners;

9. **Alternative supplier:** identification of the possibility of having multiple suppliers;

10. **Market changes:** changes in customer's behaviour (for supplier and firm refer to forecasts).

Furthermore, taking into account that supply chain visibility is the consequence of supply chain actors having access to the information, only the accessible information types need to be considered in the analysis. The visibility metric considers two properties of the accessible information, namely quantity and quality (Caridi et al., 2010 b; Caridi et al., 2013). **Quantity** refers to the amount of information available that is shared among partners while **quality** is obtained as a combination of the **timeliness** (degree to which the information is available on-time) and **accuracy** (degree to which the information is correct and precise) of the information shared (Barratt and Barratt, 2011; Caridi et al., 2010 b; Caridi et al., 2013; Kaipia and Hartiala, 2006; Williams et al., 2013). Quantity, timeliness and accuracy are the three dimensions of the model, and the logic adopted to conduct the assessment is based on the previously explained work of Caridi et al. (2010 b).

4.2. Example of visibility assessment

Starting from a generic configuration of a company's supply chain, as represented in Figure 2, our metric allows decision-makers to assess the visibility that any firm has over its supply chain by directly sharing information with their internal, upstream, and downstream partners, as shown in Figure 3.
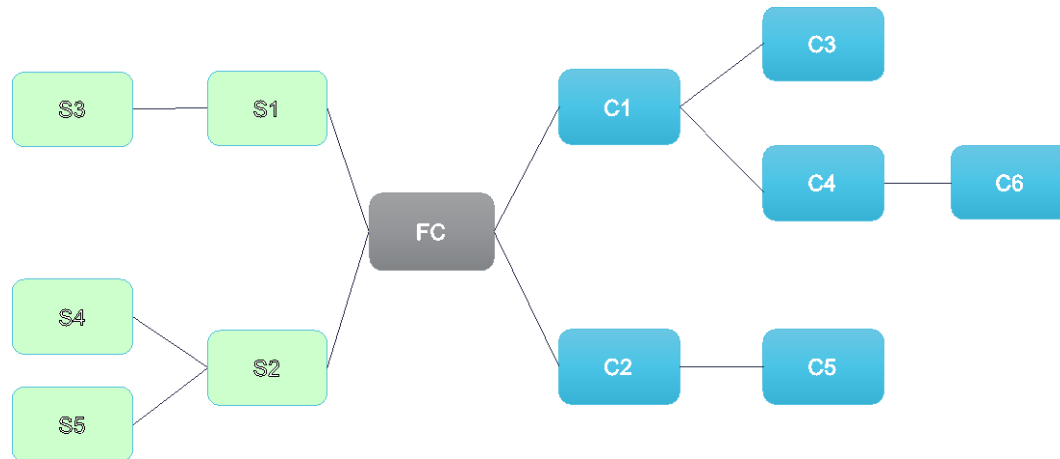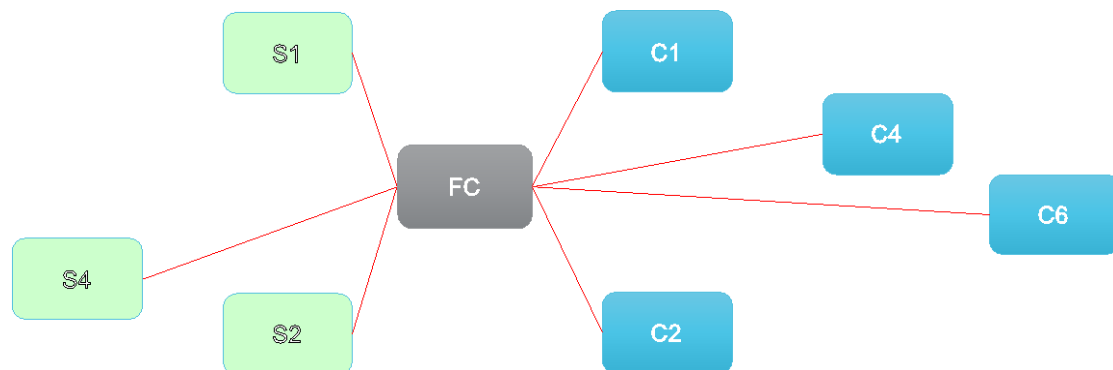

Figure 2 Company's supply chain

Figure 3 Nodes under analysis

Therefore, in this example, only the upstream nodes S1, S2, and S4, the firm itself, and customer nodes C1, C2, C4, and C6 are going to be considered for the analysis, because it is assumed in this example for explanatory purposes that the firm does not have access to information of S3, S4, C3, and C5. The term node here is used to refer to both external partners and internal functions. In order to use the metric decision-makers need to assess the quantity, timeliness, and accuracy of the available information, for each node k under analysis.

For what concern the quantity and quality, these properties are measured through the adoption of three different four-point Likert scales, in Tables 1, 2, and 3 respectively. The adoption of such quantitative scales represents a trade-off between rigor and usability of the metric (Caridi et al., 2010 b), and allows decision-makers to formulate their judgements based both on the data and on their perception.

Table 1 Scale to judge the amount of available information exchanged among partners

Score	Description
1	Unsatisfactory
2	Most of the time we ask for more information from our partner
3	In some case we ask for more information from our partners
4	Satisfactory

Table 2 Scale to judge the timeliness of the available information exchanged among partners

Score	Description
1	Unsatisfactory
2	Information is updated only upon request
3	Information is updated most of the time without request
4	Real time

Table 3 Scale to judge the accuracy of the available information exchanged

Score	Description
1	Only in few occasions
2	Sometimes
3	Most of the time
4	Always

In order to proceed with the assessment of the three dimensions, the following notation, in Table 4, is used.

Table 4 Notation for visibility judgements

	Types of information (I)									
	1	2	3	4	5	6	7	8	9	10
Quantity	$J_{q,1}$	$J_{q,2}$	$J_{q,3}$	$J_{q,4}$	$J_{q,5}$	$J_{q,6}$	$J_{q,7}$	$J_{q,8}$	$J_{q,9}$	$J_{q,10}$
Timeliness	$J_{t,1}$	$J_{t,2}$	$J_{t,3}$	$J_{t,4}$	$J_{t,5}$	$J_{t,6}$	$J_{t,7}$	$J_{t,8}$	$J_{t,9}$	$J_{t,10}$
Accuracy	$J_{a,1}$	$J_{a,2}$	$J_{a,3}$	$J_{a,4}$	$J_{a,5}$	$J_{a,6}$	$J_{a,7}$	$J_{a,8}$	$J_{a,9}$	$J_{a,10}$

After all the individual judgments have ended, it is possible to combine them adopting the geometric mean in order to obtain a comprehensive assessment of each of the three dimensions. The elementary visibility indices are presented in Table 5.

Table 5 Elementary visibility indices at node level

Index	Formula
Total amount of visible information	$\text{Visibility\_quantity}_k = \sqrt[n]{\prod_{i=1}^{n} Jq,i}$
Timeliness of the visible information	$\text{Visibility\_timeliness}_k = \sqrt[n]{\prod_{i=1}^{n} Jt,i}$
Accuracy of the visible information	$\text{Visibility\_accuracy}_k = \sqrt[n]{\prod_{i=1}^{n} Ja,i}$
Total quality of visible information	$\text{Visibility\_quality}_k = \sqrt{\text{Visibility\_timeliness}_k * \text{Visibility\_accuracy}_k}$
Overall visibility of type i information	$\text{Partial\_visibility}_{i,k} = \sqrt[3]{Jq,i * Jt,i * Ja,i}$

Where i represents the type of accessible information and n the number of types of accessible information. At this point the overall visibility of the node k can be calculated:

$$\text{Overall\_visibility}_k = \sqrt{\text{Visibility\_quantity}_k * \text{Visibility\_quality}_k}$$

For diagnostic purpose, decision-makers can use this overall visibility index to identify the nodes where improvement actions are more effective. It is also possible to obtain a more fine-grained analysis by comparing the visibility of different types of information, as shown in the last row of Table 5.

A numerical example which simulates the judgements that the decision-maker of a company (FC) makes of the dimensions of the downstream node C1, is reported in Table 6 below.

Table 6 Numerical example of node C1 judgements and visibility assessment

	I									
	1	2	3	4	5	6	7	8	9	10
Quantity	2	1	-	4	-	3	-	-	-	-
Timeliness	3	2	-	3	-	4	-	-	-	-
Accuracy	4	3	-	2	-	2	-	-	-	-

$$\text{Visibility\_quantity}_{C1} = \sqrt[4]{2 * 1 * 4 * 3} = 2,21$$

$$\text{Visibility\_timeliness}_{C1} = \sqrt[4]{3 * 2 * 3 * 4} = 2,91$$

$$\text{Visibility\_accuracy}_{C1} = \sqrt[4]{4 * 3 * 2 * 2} = 2,63$$

$$\text{Visibility\_quality}_{C1} = \sqrt{(2,91) * (2,63)} = 2,77$$

$$\text{Overall\_visibility}_{C1} = \sqrt{(\,2{,}21\,) * (2{,}77)} = 2{,}47$$

Taking into account the judgement of the individual dimensions of the model, the perceived visibility level ranges between 1 (low visibility) and 4 (high visibility). Once all the nodes have been assessed, three global visibility measures can be obtained as average of the visibility at node level of each group, namely internal, upstream, and downstream. The three visibility indices are reported in Table 7.

Table 7 Internal, upstream, and downstream visibility indices

Index	Formula
Overall visibility of the internal functions	$\text{Internal\_visibility} = \sum_{k=1}^{NI} \text{Overall\_visibility}_k$
Overall visibility of upstream partners	$\text{Upstream\_visibility} = \sum_{k=1}^{NU} \text{Overall\_visibility}_k$
Overall visibility of downstream partners	$\text{Downstream\_visibility} = \sum_{k=1}^{ND} \text{Overall\_visibility}_k$

Where *NI* represents the number of internal functions, *NU* is the number of the nodes of upstream partners, and *ND* is the number of nodes of downstream partners. Decision-makers can use these latter indices for benchmarking with competitors or with companies belonging to similar sectors.

5. Concluding remarks

The quantitative approach presented in this study contributes to both research and practice by providing a better understanding of visibility in supply chain. The approach provides a theoretical foundation for researchers interested in quantifying information for visibility instead of focusing on the consequences of the achieved visibility. Also, it provides a holistic approach for supply chain visibility in complex networks. In fact, irrespectively of the position of the firm within the supply chain, decision-makers are able to assess external visibility level, related to suppliers and customers respectively, and internal visibility level, among internal functions. This allowed to overcome the main limitations of previous renowned studies, namely Caridi et al. (2010 b) and Zhang et al. (2011), previously analysed. On the other hand, the main limitation of our study is related to the lack of a weight for node differentiation. Further research will point to this direction to differentiate supply chain nodes in terms of their relevance.

This research has also several implications for practitioners. First of all, it provides a valuable diagnostic tool for decision-makers to assess the degree of visibility of supply chain partners. Also, by intervening in the properties of the information shared the tool allows to evaluate the impact of improvements in the current degree of visibility. Although the metric provides a

global measure of supply chain visibility, an additional application could be to support decision-makers in the preparation of effective management of disruptions in complex supply chains. Secondly, the metric can be used for benchmarking purpose allowing to compare the visibility level of the firm with partners, with competitors or with companies belonging to similar sectors. Finally, the metric may be implemented into a company scorecard, in order to provide transparency of external and internal performance, and to translate performance into value creating actions. Further research will be carried out to test the accuracy and practical usability of the metric in real context, through case studies research.

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