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Composite Indicators of Company Performance: A Literature Survey

Qinqin Zeng | Wouter W.A. Beelaerts van Blokland | Sicco C. Santema | Gabriël Lodewijks

Composite indicators (CIs) are needed for decision makers to effectively benchmark holistic company performance. Composite indicators at macro levels are inappropriate to be implemented at the company level. By a literature survey, this article identified 29 individual methods for constructing CIs, 17 specific business sectors where CIs have been utilized in practice, and the motor vehicle manufacturing sector as the most studied sector. This article identified nine problems and provided four recommendations for future research.

Company performance can be defined as the efficiency and effectiveness of actions (Neely, Gregory, and Platts, 1995) for decision makers to monitor performance. Traditionally, financial performance is regarded as company performance, and financial analysis systems, such as DuPont's, are sufficient to measure this performance. However, it is acknowledged that financial performance is just one aspect of company performance. Due to the complex global business environment, company performance has evolved into an integration of both financial and non-financial indicators. Since the late 1980s, several classically integrated company performance frameworks have been developed. For example, the concept of the third generation of performance measurement system was proposed with emphasis on the adoption of non-financial indicator and intangible indicators (Neely, Marr, Roos, Pike, & Gupta, 2003). However, the integrated frameworks of company performance are multidimensional, which makes it difficult to quantify them directly.

According to the *Glossary of Statistical Terms*, a CI "is formed when individual indicators are compiled into a single index, on the basis of an underlying model of the multidimensional concept that is being measured" (Organization for Economic Cooperation and Development, 2007, p. 125). Composite indicators (CIs) have increasingly been accepted as a useful tool for benchmarking, performance comparisons, policy analysis, and public communication in many fields (Zhou, Ang, & Zhou, 2010). Company performance is a multi-dimensional concept. A way of measuring the multidimensional performance is to adopt or construct CIs that convey relevant information into a single figure.

Various techniques for constructing CIs have been elaborated in publications such as the well-known tool book, *Handbook on Constructing Composite Indicators* (Organisation for Economic Cooperation and

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Development, 2004). However, the majority of CIs derived are on social and environmental issues and at macro levels (e.g., at the national level or the regional level) (Zeng, Beelaerts Van Blokland, Santema, and Lodewijks, 2018). Composite indicators that have been utilized at the company level in specific business sectors such as the manufacturing sector are relatively limited.

The purpose of this article is to identify, categorize and discuss academic publications referencing the use of CIs of company performance measurement that have been utilized in sectors. There are two underlying motivations for the authors to write this survey article: (1) to provide an up-to-date literature survey on the existing CIs at the company level, and (2) by analyzing the references retrieved, the authors aim to identify the current problems during CIs' construction and to provide avenues for future research, which can benefit practitioners with a more transparent implementation of constructing CIs. With a better understanding about how CIs work in monitoring company performance, stakeholders such as financial institutions can effectively benchmark company performance.

This article can benefit stakeholders by describing a more transparent implementation of constructing CIs and by providing a better understanding about how CIs work in monitoring or benchmarking company performance.

The rest of the article is organized as follows. Section 2 presents the method for performing the literature survey, including research questions, the search process, and search results. Section 3 presents the literature review for the two sub-questions—namely, the literature on the techniques used for constructing CIs and the literature in terms of the CIs' utilized sectors. Section 4 consists of discussions of the general problems during CI construction and discussion of the specific problems during the CIs' construction in the most studied sector. Finally, concluding remarks, contributions, the research limitations of this article and recommendations for further research are given in Section 5.

Method

This article has been undertaken as a literature survey to identify and discuss the eligible literature referencing the use of CIs that have been utilized in various sectors. A clear and rigorous literature-survey method is demanded as the very first step in the literature-survey processes. The literature survey in this article is based on the general preferred reporting items specified by Moher, Liberati, Tetzlaff and Altman (2009) as well as the guidelines proposed by Keele (2007). Moher et al. (2009) proposed a checklist of items to include when reporting a systematic review or meta-analysis. Items such as eligibility criteria, information sources, search, data collection process, and summary measures are included. Keele (2007, p. 6) summarized three main phases in a literature review: (1) planning

the review, (2) conducting the review, and (30 reporting the review. In this article, the research question is specified in the planning-the-review phase. The search processes are specified in the conducting-the-review phase. The search result is presented in the reporting-the-review phase. The three phases are documented in the following subsections.

Research Questions

This article tries to answer the research question (RQ): Which CIs are recognized in the literature? Based on this RQ, three research sub-questions are listed as follows.

RQ_1: Which techniques are used for constructing the CIs?

It's crucial to understand the techniques for constructing CIs, because there are various kinds of techniques with pros and cons for constructing CIs. If properly conceived, CIs can work as an effective statistical tool for calculating and analysing performance. However, CIs can "send misleading policy messages if poorly or misinterpreted constructed" (Joint Research Centre-European Commission, 2008, p. 13).

There are several steps to be followed in constructing CIs. A crucial role is played by the concept of *weighting the variables* (Munda & Nardo, 2005). In addition, Freudenberg (2003) discussed other crucial steps, including the step for identifying and developing relevant variables, the step for standardizing variables to allow comparisons, the step for weighting variables and groups of variables, and the step for conducting sensitivity tests on the robustness of aggregated variables.

This article focuses on five steps, including the step for selecting variables, the step for normalizing the measures, the step for weighting the variables, the step for aggregating individual variables into a single one, and the step for post-analyzing the CIs derived. In order to answer RQ_1, the techniques used in the CIs need to be identified and their distribution among the literature need to be presented.

RQ_2: Given the CIs identified from RQ_1, in which business sectors have these CIs been utilized in practice, and which sector is the most studied?

The North American Industry Classification System (abbreviated as NAICS) is a classification of business sectors by type of economic activity. Various specific sectors such as the transportation-equipment-manufacturing sector are included in 2017 NAICS Sectors (United States Census Bureau, 2017). The background in practice varies from one sector to another.

However, the construction of CIs cannot be directly generalized from one sector to another. In other words, variables as well as their weights vary from one sector to another. This is in line with the statement that performance measurement needs to be based on sectors exclusively due to reasons such as sector gaps (Yildiz, Hotamisli, & Eleren, 2011). In order

to answer RQ_2, the sectors in which the CIs are utilized must be identified, and their distribution among the literature must be presented.

Search Processes

Keywords search

In this article, literature is reviewed in light of the following topics: (a) company performance measurement and (b) composite indicator. Keywords are collected based on the research question and the two sub-questions. This process entailed keyword searches for *composite indicator*, *index*, *indices*, *company performance*, *performance measurement*; *company assessment*, and *performance indicator*. The keyword search queries are listed in Table 1. Afterwards, as shown in Table 2, this article takes two steps as the literature search strategy. Step one involves 14 inclusion criteria and step two involves three exclusion criteria.

Step one: 14 inclusion search criteria.

C_1 - C_3: Collect potential references via the three sources. Although there are many sources that could be used for the literature search, this article focuses on Web of Science core collection, Scopus, and Google Scholar. Web of Science Core Collection indexes primary journals and article citations in several databases spanning a wide range of disciplines. Scopus and Google Scholar are chosen because (a) they cover the world's scientific and scholarly literature comprehensively (Aksnes & Sivertsen, 2019), (b) they are similar to Web of Science in that they were created primarily for citation searching, and (c) they represent major competitors to Web of Science in the field of bibliometrics (Yang & Meho, 2006).

C_4: The literature search dates back to the year 2004, considering 2004 as the year when Google Scholar was launched and the most accepted concept of composite indicator was presented at the OECD Committee on Statistics (Organization for Economic Cooperation and Development, 2007, p.5).

C_5 - C_7: Select articles as full papers published in academic journals. In other words, the documents type for Web of Science core collection is *Article,* for Google Scholar is *Article*, and for Scopus is *Articles*.

C_8 - C_{10}: Select field tags where keywords will be searched. The field tags for Web of Science core collection is *In Title;* for Google Scholar it is *anywhere in the article*; and for Scopus it is *In Abstract title, Abstract, keywords*.

C_{11}: Choose the language of the articles as English.

TABLE 1 KEYWORD SEARCH QUERIES

	COMBINE WITH AND	
Combine with **OR**	company performance	composite indicator
	performance measurement	index
	company assessment	indices

TABLE 2 CRITERIA FOR REFERENCE RETRIEVAL

STEP	CRITERION	CONTENT
1)	Database	C_1 Web of Science Core Collection C_2 Google Scholar C_3 Scopus
	Time Span	C_4 From 2004 to 2018
	Document Types	C_5 Article C_6 Articles C_7 Article
	Search Keywords from	C_8 In title C_9 Anywhere in the article C_{10} In Abstract title, Abstract, keywords
	Language	C_{11} English
	Research/ Subject Areas	C_{12} Mathematics; Operations research management science; Business economics; Social issues; Mathematical methods in social sciences C_{13} Mathematics; Business, Management and Accounting; Decision Sciences; Multidisciplinary; Social Science; Economics, Econometrics and Finance
	Web of Science Categories	C_{14} Mathematics applied; Mathematics interdisciplinary applications; Mathematics; Statistics probability; Operations research management science; Economics; Multidisciplinary sciences; Business; Business finance; Management; Social sciences mathematical methods; Ecology; Social issues
2)	Inclusion and Exclusionary	C_{15} Duplication Checking with EndNote C_{16} Articles with CIs that are not utilized in sectors at the company level C_{17} Articles that are without focus on quantitative models/ techniques for constructing CIs.

C_{12} - C_{13}: scope the research subject/area of the literature search. This article is in the field of company performance management and management. Therefore, for Web of Science core collection, the research subject/area includes being scoped as Mathematics, Operations research management science, Business economics, Social issues; Mathematical methods in social sciences. For Scopus the research subject/area includes Mathematics; Business, Management, and Accounting; Decision Sciences; Multidisciplinary; Social Science; and Economics, Econometrics, and Finance.

C_{14}: For Web of Science core collection, the literature search can be scoped further by setting up the Web of Science categories as Mathematics applied, Mathematics interdisciplinary applications, Mathematics, Statistics probability, Operations research management science, Economics, Multidisciplinary sciences, Business, Business finance, Management, Social sciences mathematical method,; Ecology, and Social issues.

In summary, for Web of Science Core Collection, the inclusion criteria include C_1, C_4, C_5, C_8, C_{11}, C_{12} and C_{14}. For Google Scholar, the inclusion criteria include C_2, C_4, C_6, C_9 and C_{11}. For Scopus, the inclusion criteria include C_3, C_4, C_7, C_{10}, C_{11} and C_{13}.

Step two: three exclusion search criteria.

Double check the literature by excluding.

1. **C_{15}**: The article that is a duplicate reference from EndNote—in other words, articles that are overlapped in Web of Science core collection, Scopus, or Google Scholar.
2. **C_{16}**: When its full text is examined, the article mentions the CI that is not utilized in sectors at the company level.
3. **C_{17}**: Articles, such as the one by Digalwar, Jindal and Sangwan (2015) that have a focus on developing theoretical frameworks with indicators but without focus on quantitative models/techniques for constructing CIs.

Search Results

The search result is shown in Figure 1 (refer the meanings of C_1 - C_{17} to the previous section).As is seen in Figure 1, after performing step one with the inclusion criteria C_1 - C_{14}, this article searched 56469 potential articles. After performing step two with the exclusion criteria C_{15} - C_{17}, this article finally identified 51 individual articles with CIs that are utilized in sectors at the company level. Twenty five articles are from Web of Science Core Collection, 11 articles are from Google Scholar, and 15 articles are from Scopus. The information about the CIs—the authors

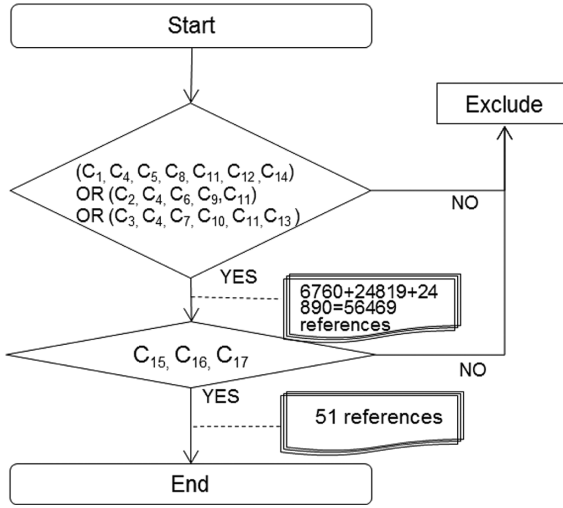

FIGURE 1 THE LITERATURE SEARCH STRATEGY

Note: Refer to the last section, Section search processes, for the meaning of C_1 to C_{17}

TABLE 3 SEARCH RESULT: THE NAME OF THE CIS, THE AUTHORS WITH THE PUBLICATION YEAR, AND THE CI'S UTILIZED CONTEXT

NO.	NAME OF THE CI	AUTHOR (YEAR), SOURCE[a]	THE CI'S UTILIZED CONTEXT
1	An airline-safety index	Chang and Yeh (2004), C_1	Four major airlines in China
2	A knowledge-management performance index	Lee, Lee, and Kang (2005), C_1	101 firms in Korea
3	A financial performance index	Sohn, Kim, and Moon (2007), C_1	1,152 firms in Korea
4	A governance Index	Chen, Kao, Tsao, and Wu (2007), C_1	3,233 fifirm in China
5	A sustainability performance index	Singh, Murty, Gupta, and Dikshit (2007), C_1	A steel company in India
6	An air force logistics-management index	Yoon, Kim, and Sohn, (2008), C_1	Airforce sector in Korea
7	A hierarchical assessment index	Grimaldi and Cricelli, (2009), C_1	- [b], - [c]
8	A total performance index	Hwang, Lee, Liu, and Ouyang (2009), C_3	35 commercial banks in China
9	Packaging and recycling index	Qalyoubi-Kemp (2009), C_2	Commercial packaging companies in the USA
10	A fuzzy intellectual-capital index	Kale (2009), C_1	Construction firms in Turkey
11	A socially responsible property-investment index	Newell (2009), C_3	11 property companies in the UK
12	A transparency index	Cheung, Jiang, and Tan (2010), C_2	100 companies in China
13	An over index of suppliers	Amrina and Yusof (2010), C_2	Automotive SEM[d] companies in Malaysia
14	A leanness index	Singh, Garg, and Sharma (2010), C_2	An automobile company in India
15	Global corporate social responsibility rate	Focacci (2011), C_3	Three companies, - [c]
16	An average value leverage index	Beelaerts van Blokland et al. (2012), C_2	Aircraft manufacturers, engine manufacturers and large suppliers, - [c]
17	A sustainability index	Zhou, Tokos, Krajnc, and Yang (2012), C_3	A brewery, - [c]
18	A metafrontier non-radial Malmquist CO_2 emission performance index	Zhang and Choi (2013), C_2	259 fossil fuel power plants in China
19	A corporate performance index	Erbetta, Menozzi, Corbetta, and Fraquelli (2013), C_3	320 companies in 10 sectors in Italy
20	A ranking index	Blancas, Contreras, and Ramírez-Hurtado (2013), C_2	The fast-food franchising sector in Spain
21	An overall performance index of suppliers	Chahid, El Alami, Soulhi, and El Alami (2014), C_3	Automotive companies in Morocco
22	An integrated lean index	Wong, Ignatius, and Soh (2014), C_2	A semiconductor manufacturing company in Malaysia

TABLE 3 CONTINUED

NO.	NAME OF THE CI	AUTHOR (YEAR), SOURCE[a]	THE CI'S UTILIZED CONTEXT
23	A psychosocial risk indicator	Bergh, Hinna, Leka, and Jain (2014), C_3	An oil and gas company in Norway
24	A sustainability assessment index	Garbie (2014), C_3	An aluminum manufacturing company in Sultanate of Oman
25	A scheduling performance evaluation index	Liu, Liang, Wang, Liu, and Xie (2014), C_3	Baoyun Logistics Company in China.
26	A circular economy efficiency composite index	Ma, Wen, Chen, and Wen (2014), C_3	Private steel enterprises in China
27	A sustainability performance index	Mohamed, Jenatabadi, and Hasbullah (2015), C_3	Food process manufacturers in China and Malaysia
28	A sustainable supply chain performance index	Gopal and Thakkar (2015), C_3	An automobile company in India
29	A sustainability index	Salvado, Azevedo, Matias, and Ferreira (2015), C_3	An automotive company in Portugal
30	An efficiency assessment index	Zanella, Camanho, and Dias (2015), C_3	Hydropower plants in Brazil
31	3 lean transaction cost efficiency indicators	de Jong and Beelaerts van Blokland (2015), C_3	An aircraft maintenance repair and overhaul service company, -[c]
32	A sustainability index	Harik, El Hachem, Medini, and Bernard (2015), C_3	Six food manufacturing companies, -
33	A social and environmental disclosure index	Monica and Gagan (2015), C_1	41 companies in India
34	An automotive supplier selection weighted Index	Ayağ and Samanlioglu (2016), C_1	Automotive suppliers in Turkey
35	A performance-evaluation model	Li and Zhao (2016), C_1	5 thermal power plants in China
36	A multiple criterion appraisement index	Sahu, Sahu, and Sahu (2016), C_1	-[b], -[c]
37	A sustainable business excellence index	Metaxas, Koulouriotis, and Spartalis (2016), C_1	An insulating materials manufacturer, -[c]
38	A corporate governance index	Nerantzidis (2016), C_1	-[b], in Greece
39	Corporate social responsibility index	Paredes-Gazquez, Rodriguez-Fernandez, and de la Cuesta-Gonzalez (2016), C_1	74 companies from 32 countries
40	A sustainability reporting index	Garg (2017), C_1	17 food and agro-products companies in India
41	A product-liability index	Seo and Bae (2017), C_1	40 manufacturers in 11 sectors in Korea
42	A dynamic Luenberger indicator	Mendola and Volo (2017), C_1	123 commercial banks and 265 cooperative Shinkin banks, in Japan

TABLE 3 CONTINUED

NO.	NAME OF THE CI	AUTHOR (YEAR), SOURCE[a]	THE CI'S UTILIZED CONTEXT
43	A performance index of risk and governance structure	Tinggi, Hla, Jakpar, Cheuk, and Nichol (2017), C_1	390 companies in Malaysia
44	A competitiveness-assessment index	Zhang, Chen, and Liu (2017), C_1	An aviation and aerospace manufacture in China
45	A corporate sustainability index	Kocmanova, Docekalova, and Simanaviciene (2017), C_1	211 manufacturing companies in the Czech Republic
46	An average value leverage factor	Beelaerts van Blokland, van de Koppel, Lodewijks, and Breen (2019), C_2	Vehicle manufacturers, - [c]
47	A sustainable circular index	Azevedo, Godina, and Matias (2017), C_1	Manufacturing companies, -
48	A composite indicator of corporate sustainability	Engida, Rao, Berentsen, and Oude Lansink (2018), C_2	Companies in the European food and beverages sector, - [c]
49	A multidimensional innovation index	Pereira, Araújo, and Costa (2018), C_1	Metalworking SMEs in Portugal
50	A composite leading indicator	Rubio-Romero, Pardo-Ferreira, De la Varga-Salto, and Galindo-Reyes (2018), C_1	A company responsible for the public collection and delivery of solid urban waste in Spain
51	A green index	Rita, Ferreira, Meidutė-Kavaliauskienė, Govindan, and Ferreira (2018), C_1	8 SEMs[d], - [c]

Note: [a.] Database source. C_1 stands for Web of Science Core Collection; C_2 stands for Google Scholar; C_3 stands for Scopus
[b.] unclear information of sectors in the article
[c.] unclear information of the geographical distribution in the article
[d.] SEMs means small and medium-sized enterprises

with the publication year and the CI's utilized context—are listed in Table 3.

Review of the Literature

As mentioned in the Method section, this article focuses on five steps including the step for selecting variables, the step for normalizing the measures, the step for weighting the variables, the step for aggregating individual variables into a single one, and the step for post-analyzing the CIs derived. To answer RQ_1 and RQ_2, the literature review in terms of the techniques used during the five steps and in terms of the CIs' utilized sectors is conducted in the following subsection.

Literature in Terms of Techniques for Constructing CIs

As is shown in Figure 2, for each of the five steps, there are various kinds of techniques used in the identified 51 articles.

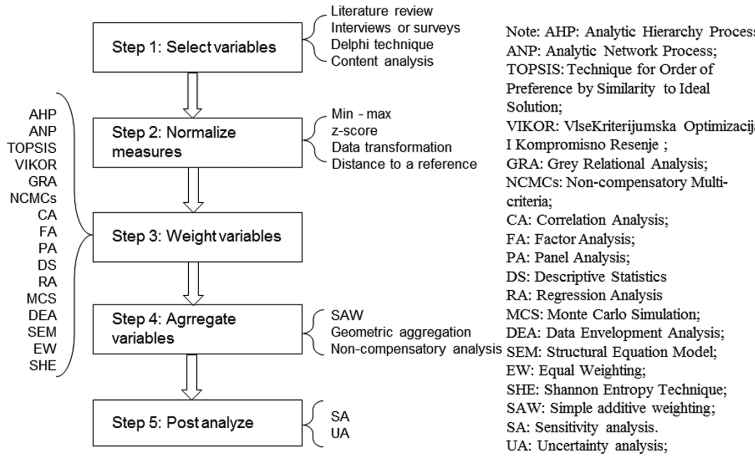

FIGURE 2 THE FIVE STEPS AND TECHNIQUES USED FOR CONSTRUCTING CIS

TABLE 4 A LIST OF INTEGRATED COMPANY PERFORMANCE FRAMEWORKS

NO.	NAME	REFERENCE
1	Performance criteria system	Globerson (1985)
2	Activity-based costing system	Cooper and Kaplan (1987)
3	Performance measurement questionnaire	Dixon(1990)
4	Performance measurement for world-class manufacturer	Maskell(1991)
5	Results and determinants matrix	Brignall and Ballantine (1996)
6	Balanced scorecard	Kaplan and Norton (1995)
7	Consistent performance measurement systems	Flapper, Fortuin, and Stoop (1996)
8	Integrated performance measurement systems reference model	Bititci (1997)
9	Comparative business scorecard	Kanji (1998)
10	Integrated dynamic performance measurement systems	Bititci, Turner, and Begemann (2000)
11	Performance prism	Neely and Adams (2002 hum)
12	Dynamic multi-dimensional performance framework	Maltz, Shenhar, and Reilly (2003)
13	European foundation for quality management	Wongrassamee, Simmons, and Gardiner (2003)

Techniques for selecting variables.

The step of selecting variables for constructing CIs is usually done by referring to company-performance frameworks accepted and used by companies. Table 4 lists 13 well known integrated company-performance frameworks.

In general, identifying and validating the underlying indicators can be undertaken through an extensive literature review on available measures

and existing indices. In addition, there are three main techniques as follows. In the survey in this article, 31 articles adopt literature review, 16 articles adopt interviews or surveys, 5 articles adopt content analysis, and 4 articles adopt the Delphi technique. The technique, the references that applied the technique, and the proportion the technique makes up in the 51 references are shown in Table 5.

The Delphi technique.

The Delphi technique is a highly formalized technique of communication (Dalkey & Helmer, 1963) that is designed to extract the maximum

TABLE 5 A LIST OF SELECTING-VARIABLES TECHNIQUES WITH THE REFERENCES

NO.	TECHNIQUE	REFERENCES	PROPORTION
1	**Literature review**	Chang and Yeh (2004); Lee, Lee, and Kang (2005); Chen, Kao, Tsao, and Wu (2007); Singh, Murty, Gupta, and Dikshit (2007); Yoon, Kim, and Sohn, (2008); Grimaldi and Cricelli, (2009); Qalyoubi-Kemp (2009); Kale (2009); Newell (2009); Beelaerts van Blokland et al. (2012); Erbetta, Menozzi, Corbetta, and Fraquelli (2013); Blancas, Contreras, and Ramírez-Hurtado (2013); Wong, Ignatius, and Soh (2014); Bergh, Hinna, Leka, and Jain (2014); Garbie (2014); Liu, Liang, Wang, Liu, and Xie (2014); Zanella, Camanho, and Dias (2015); de Jong and Beelaerts van Blokland (2015); Harik, El Hachem, Medini, and Bernard (2015); Sahu, Sahu, and Sahu (2016); Metaxas, Koulouriotis, and Spartalis (2016); Nerantzidis (2016); Paredes-Gazquez, Rodriguez-Fernandez, and de la Cuesta-Gonzalez (2016); Garg (2017); Seo and Bae (2017); Mendola and Volo (2017); Tinggi, Hla, Jakpar, Cheuk, and Nichol (2017); Zhang, Chen, and Liu (2017); Beelaerts van Blokland, van de Koppel, Lodewijks, and Breen (2019); Azevedo, Godina, and Matias (2017); Rubio-Romero, Pardo-Ferreira, De la Varga-Salto, and Galindo-Reyes (2018).	31/51 ≈60.78%
2	Interviews or surveys	Chang and Yeh (2004); Lee, Lee, and Kang (2005); Yoon, Kim, and Sohn, (2008); Hwang, Lee, Liu, and Ouyang (2009); Kale (2009); Wong, Ignatius, and Soh (2014); Bergh, Hinna, Leka, and Jain (2014); Ma, Wen, Chen, and Wen (2014); Harik, El Hachem, Medini, and Bernard (2015); Nerantzidis (2016); Garg (2017); Seo and Bae (2017); Zhang, Chen, and Liu (2017); Azevedo, Godina, and Matias (2017); Pereira, Araújo, and Costa (2018); Rubio-Romero, Pardo-Ferreira, De la Varga-Salto, and Galindo-Reyes (2018).	16/51 ≈31.37%
3	**Content analysis**	Salvado, Azevedo, Matias, and Ferreira (2015); de Jong and Beelaerts van Blokland (2015); Monica and Gagan (2015); Azevedo, Godina, and Matias (2017); Rita, Ferreira, Meidutė-Kavaliauskienė, Govindan, and Ferreira (2018).	5/51 ≈9.80%
4	**Delphi technique**	Nerantzidis (2016); Seo and Bae (2017); Azevedo, Godina, and Matias (2017); Rubio-Romero, Pardo-Ferreira, De la Varga-Salto, and Galindo-Reyes (2018).	4/51 ≈7.84%

Notes: the Proportion is calculated as the number of the references for each technique divided by 51 which is the number of total articles.

amount of unbiased information from a panel of experts (Chan, Yung, Lam, Tam, & Cheung, 2001), which could be used to assess uncertainty in a quantitative manner. Some studies used the Delphi technique to finalize the indicators or to quantitatively weigh the variables.

Interviews or surveys.

Interviews or surveys are used to obtain more information for choosing the underlying indicators; afterwards, the consistency of the results obtained from this process should be verified. The Cronbach Coefficient Alpha (Cronbach, 1951) is often used to measure internal consistency. The MegaStat application can be used for calculating the coefficient.

Content analysis.

Content analysis is used for identifying the underlying variables by referring to some documents from companies' annual reports, Global Reporting Initiative, the ISO 14031and so forth. The value stream mapping technique and the cognitive mapping technique can be included when using this technique.

Techniques for normalizing variables.

The frequently used techniques are standardization (also known as z-score normalization), min-max normalization (also known as re-scaling by minimum method), data transformation based on given values, categorical scales, ratio-scale methods, the percentages of annual differences over consecutive years, and the distance to a reference. In addition, there are several nonlinear normalization techniques such as logarithm function, expectation function, and arc-tangent function.

The technique, the source for the technique, references in which the technique was applied, and the amount the technique makes up in the 51 references are shown in Table 6. In summary, 9 out of 51 articles contain explanation of the normalization process, and the remaining 42 articles are without a clear normalization process.

Basically, there are three categories of variables. In one category the higher value the variable has, the better performance in terms of the variable is. In the second category the lower value the variable has, the better performance in terms of the variable is.

In the final category there is a nominal value for the variable to be the best. Among the 51 articles, there are 6 articles that consider variables' different categories.

Techniques for weighting variables.

In the step of weighting variables, basically there are two categories as follows. Besides, there are some studies used an integrated technique of both direct explication and indirect explication for weight determination,

TABLE 6 REFERENCES DISTRIBUTION IN TERMS OF NORMALIZATION TECHNIQUES

NO.	TECHNIQUE; ITS SOURCE	REFERENCE(S)	PROPORTION
1	Min-max normalization; Dodge (2006)	Focacci (2011); Zhou, Tokos, Krajnc, and Yang (2012); Salvado, Azevedo, Matias, and Ferreira (2015); Harik, El Hachem, Medini, and Bernard (2015); Azevedo, Godina, and Matias (2017)	5/51 ≈9.80%
2	z-score normalization; Zill, Wright, and Cullen (2011)	Singh, Murty, Gupta, and Dikshit (2007); Hwang, Lee, Liu, and Ouyang (2009); Zhou, Tokos, Krajnc, and Yang (2012)	3/51 ≈5.88%
3	Data transformation based on given values; Dodge (2006)	Beelaerts van Blokland et al. (2012); Ma, Wen, Chen, and Wen (2014)	2/51 ≈3.92%
4	Distance to a reference; Hope and Parker (1995)	Salvado, Azevedo, Matias, and Ferreira (2015); Monica and Gagan (2015); Azevedo, Godina, and Matias (2017)	3/51 ≈5.88%
5	Percentages of annual differences over consecutive years; Nardo et al. (2004)	Zhou, Tokos, Krajnc, and Yang (2012)	1/51 ≈1.96%

Note: the Proportion is calculated as the number of the references for each technique divided by 51 which is the number of total articles.

in order to do comparisons or in order to make good use of experts' practical experience and make the extra use of objective weighting technique. A list of the technique, the source for the technique, references which applied the technique and the proportion the technique makes up in the 51 references are shown in Table 7.

One category is the direct explication. It involves collecting scores via experts in a subjective manner, and then calculating the weights with multi-criteria decision making (MCDM) techniques. MCDM is one of the most widely used methodologies in fields like business and economy (Mardani et al., 2015; Rabbani, Zamani, Yazdani-Chamzini, and Zavadskas, 2014). Commonly used MCDM techniques include Analytic Hierarchy Process (AHP); Analytic Network Process (ANP); VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR); Grey Relational Analysis (GRA); Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS); Non-compensatory Multi-criteria (NCMCs), Decision Aid for Multi Attribute Evaluation Using Imprecise Weight Estimates by Jessop (2014), Best-Worst Method (BWM) by Rezaei (2016) and Decision-Making Trial and Evaluation Laboratory (DEMATEL) by The Science and Human Affairs Program of Battelle Memorial Institute of Geneva.

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TABLE 7 REFERENCES DISTRIBUTION IN TERMS OF WEIGHTING TECHNIQUES

CATEGORY	TECHNIQUE; ITS SOURCE		REFERENCE(S)	PROPORTION
Direct explication	**MCDM**	AHP; Saaty (1987)	Chen, Kao, Tsao, and Wu (2007); Grimaldi and Cricelli, (2009); Amrina and Yusof (2010); Chahid, El Alami, Soulhi, and El Alami (2014); Wong, Ignatius, and Soh (2014); Garbie (2014); Gopal and Thakkar (2015); Salvado, Azevedo, Matias, and Ferreira (2015); Harik, El Hachem, Medini, and Bernard (2015); Metaxas, Koulouriotis, and Spartalis (2016); Nerantzidis (2016); Seo and Bae (2017); Zhang, Chen, and Liu (2017); Rita, Ferreira, Meidutė-Kavaliauskienė, Govindan, and Ferreira (2018)	14/51 ≈27.45%
		ANP Saaty (2005)	Wong, Ignatius, and Soh (2014); Ayağ and Samanlioglu (2016)	2/51 ≈3.92%
		TOPSIS; Lai, Liu, and Hwang (1994)	Sahu, Sahu, and Sahu (2016); Metaxas, Koulouriotis, and Spartalis (2016)	2/51 ≈3.92%
		VIKOR; Duckstein and Opricovic (1980)	Li and Zhao (2016)	1/51 ≈1.96%
		GRA; Deng (1982)	Li and Zhao (2016)	1/51 ≈1.96%
		NCMCs; Cook, Golan, Kazakov, and Kress (1988)	Zhou, Tokos, Krajnc, and Yang (2012)	1/51 ≈1.96%

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TABLE 7 CONTINUED

CATEGORY	TECHNIQUE; ITS SOURCE		REFERENCE(S)	PROPORTION
Indirect explication	STs	CA; Dodge (2006)	Chen, Kao, Tsao, and Wu (2007); Hwang, Lee, Liu, and Ouyang (2009); Newell (2009); Beelaerts van Blokland et al. (2012); Liu, Liang, Wang, Liu, and Xie (2014); de Jong and Beelaerts van Blokland (2015); Paredes-Gazquez, Rodriguez-Fernandez, and de la Cuesta-Gonzalez (2016); Zhang, Chen, and Liu (2017); Beelaerts van Blokland, van de Koppel, Lodewijks, and Breen (2019)	9/51 ≈17.65%
		FA; Kim and Mueller (1978)	Lee, Lee, and Kang (2005); Sohn, Kim, and Moon (2007); Yoon, Kim, and Sohn, (2008); Garg (2017); Kocmanova, Docekalova, and Simanaviciene (2017)	5/51 ≈9.80%
		PA; Blundell and Bond (1998)	Cheung, Jiang, and Tan (2010); Mendola and Volo (2017); Tinggi, Hla, Jakpar, Cheuk, and Nichol (2017)	3/51 ≈5.88%
		DS; Dodge (2006)	Qalyoubi-Kemp (2009); Cheung, Jiang, and Tan (2010); Rubio-Romero, Pardo-Ferreira, De la Varga-Salto, and Galindo-Reyes (2018)	3/51 ≈5.88%
		RA; Rawlings, Pantula, and Dickey (2001)	Beelaerts van Blokland et al. (2012); Monica and Gagan (2015)	2/51 ≈3.92%
		PCA; Wold, Esbensen, and Geladi (1987)	Engida, Rao, Berentsen, and Oude Lansink (2018)	1/51 ≈1.96%
	MTs	DEA; Seiford and Thrall (1990)	Zhou, Tokos, Krajnc, and Yang (2012); Zhang and Choi (2013); Erbetta, Menozzi, Corbetta, and Fraquelli (2013); Blancas, Contreras, and Ramírez-Hurtado (2013); Zanella, Camanho, and Dias (2015); Paredes-Gazquez, Rodriguez-Fernandez, and de la Cuesta-Gonzalez (2016); Seo and Bae (2017); Kocmanova, Docekalova, and Simanaviciene (2017); Engida, Rao, Berentsen, and Oude Lansink (2018)	9/51 ≈17.65%
		SEM; Issac (1970)	Sohn, Kim, and Moon (2007); Yoon, Kim, and Sohn, (2008); Mohamed, Jenatabadi, and Hasbullah (2015); Kocmanova, Docekalova, and Simanaviciene (2017)	4/51 ≈7.84%
		EW; Einhorn and Hogarth (1975)	Chen, Kao, Tsao, and Wu (2007); Zhou, Tokos, Krajnc, and Yang (2012); Beelaerts van Blokland, van de Koppel, Lodewijks, and Breen (2019)	3/51 ≈5.88%
		MCS; Mooney (1997)	Paredes-Gazquez, Rodriguez-Fernandez, and de la Cuesta-Gonzalez (2016)	1/51 ≈1.96%
		SHE; Shannon (1948)	Li and Zhao (2016)	1/51 ≈1.96%
Integration			Zhou, Tokos, Krajnc, and Yang (2012); Gopal and Thakkar (2015); Li and Zhao (2016)	3/51 ≈5.88%

Note: the Proportion is calculated as the number of the references for each technique divided by 51 which is the number of total articles.

The other category is indirect explication. It involves weighting objectively via statistical-based tools (STs) or maths techniques (MTs). Commonly used STs include Correlation Analysis (CA); Factor Analysis (FA); Panel Analysis (PA); Descriptive Statistics (DS) and Regression Analysis (RA). Commonly used MTs include Data Envelopment Analysis (DEA) with Benefit of the Doubt (BoD) included; Structural Equation Model (SEM); Equal Weighting (EW); Shannon Entropy Technique (SHE); Monte Carlo Simulation (MCS); linear programming and logistic regression.

Techniques for aggregating variables.

Following the phases of weighting and normalization for each indicator, aggregation techniques are needed to integrate those individual indicators into a bigger picture. The linear aggregation method is useful when all individual indicators have the same measurement unit, while geometric aggregations are better suited if the modeler wants some degree of non-compensability (Joint Research Centre-European Commission, 2008, p. 32). The technique, the source for the technique, the references that applied the technique, and the proportion the technique makes up in the 51 references are shown in Table 8.

SAW is also known as weighted linear combination. SAW is widely used in practice due to its transparency and ease of understanding for non-experts (Zhou, Ang, & Poh, 2006). However, as a linear aggregation model it easily becomes controversial due to the rules of preference independence and compensability among the different individual indicators.

Geometric aggregation (e.g., the weighted product method) entails partial compensability. This aggregation is a dimensionless analysis,

TABLE 8 REFERENCES DISTRIBUTION IN TERMS OF AGGREGATION TECHNIQUES

NO.	TECHNIQUE; ITS SOURCE	REFERENCES	PROPORTION
1	SAW; Keeney and Raiffa (1993)	Sohn, Kim, and Moon (2007); Chen, Kao, Tsao, and Wu (2007); Yoon, Kim, and Sohn, (2008); Hwang, Lee, Liu, and Ouyang (2009); Newell (2009); Amrina and Yusof (2010); Focacci (2011); Beelaerts van Blokland et al. (2012); Zhou, Tokos, Krajnc, and Yang (2012); Chahid, EL ALAMI, Soulhi, and El Alami (2014); Ma, Wen, Chen, and Wen (2014); Harik, El Hachem, Medini, and Bernard (2015); Ayağ and Samanlioglu (2016); Nerantzidis (2016); Beelaerts van Blokland, van de Koppel, Lodewijks, and Breen (2019); Azevedo, Godina, and Matias (2017)	16/51 ≈31.37%
2	Geometric aggregation; Bouyssou and Vansnick (1986)	Zhou, Tokos, Krajnc, and Yang (2012); Erbetta, Menozzi, Corbetta, and Fraquelli (2013); Blancas, Contreras, and Ramírez-Hurtado (2013)	3/51 ≈5.88%

Note: the Proportion is calculated as the number of the references for each technique divided by 51 which is the number of total articles.

appropriate for cases with variables with the use of a different ratio or interval scale. It is frequently used at the national level. It is emphasized that countries should focus more on increasing the weak variable with the lowest score in order to improve its overall ranking position.

Techniques for post-analyzing CIs.

Finally, the post-analysis should be performed to assess the robustness of the CIs derived in terms of the normalization scheme, the imputation of missing data (Saisana, Saltelli, & Tarantola, 2005), the aggregation technique, and so on. In this step, the combination of uncertainty analysis and sensitivity analysis (SA) is a power tool for gagging the robustness and increasing the transparency of the CIs derived. Uncertainty analysis (UA) focuses on how uncertainty in the input factors propagates through the structure of the CI and affects the CI values. SA is an integral part of model development and involves analytical examination of input parameters to aid in model validation (Hamby, 1995). With the use of SA, it can be determined how the variation in the CI is connected qualitatively or quantitatively, to the different sources of variation within the assumptions (Nardo et al., 2004). The most often used technique for SA is the variance-based technique. It is used for both dependent and independent input factors and can be implemented in the freely distributed software SIMLAB. In this article, only Wong, Ignatius, and Soh (2014) and Rita, Ferreira, Meidutė-Kavaliauskienė, Govindan, and Ferreira (2018) have performed the post-analysis step.

Literature in terms of CIs' utilized sectors.

As is shown in Table 9, among the 51 articles 30 articles mention the specific individual sector for CIs' application in the case studies, 3 of 51 articles are applied into multiple sectors, and 18 of 51 articles do not mention the specific utilized sector. According to the classification by North American Industry Classification System (2017 NAICS), this article lists the CIs' utilized sectors and the references shown in Table 9.

As to the distribution in terms of geographical areas, as is seen in Table 10, 11 out of 51 articles haven't mentioned the specific geographical area information of the CIs' application. Gopal and Thakkar (2015) report a case study in both China and Malaysia, and Garg (2017) reports case studies in 23 countries. As to the remaining 39 of 51 articles, the most distributed continent is Asia, especially with China as the biggest distribution geographical area. The second biggest distribution is in Europe with five articles. There are two articles applied to companies in America and one article applied to companies in Africa.

Literature in the most studied sector.

According to the classification by 2017 NAICS, the Motor Vehicle Manufacturing sector (code: 3361) consists of two sub-sectors—namely, automobile and light-duty motor vehicle manufacturing sector (code: NAICS 33611)

TABLE 9 REFERENCES DISTRIBUTION IN TERMS OF APPLIED SECTORS

NO.	CODE (NAICS)	SECTOR	REFERENCES	PROPORTION
1	3361	**Motor Vehicle Manufacturing**	Amrina and Yusof (2010); Singh, Garg, and Sharma (2010); Chahid, El Alami, Soulhi, and El Alami (2014); Gopal and Thakkar (2015); Salvado, Azevedo, Matias, and Ferreira (2015); Ayağ and Samanlioglu (2016); Beelaerts van Blokland, van de Koppel, Lodewijks, and Breen (2019)	7/51 ≈13.73%
2	3364	**Aerospace Product and Parts Manufacturing**	Chang and Yeh (2004); Yoon, Kim, and Sohn, (2008); Beelaerts van Blokland et al. (2012); de Jong and Beelaerts van Blokland (2015); Zhang, Chen, and Liu (2017)	5/51 ≈9.80%
3	311	Food Manufacturing	Blancas, Contreras, and Ramírez-Hurtado (2013); Mohamed, Jenatabadi, and Hasbullah (2015); Harik, El Hachem, Medini, and Bernard (2015); Garg (2017); Engida, Rao, Berentsen, and Oude Lansink (2018)	5/51 ≈9.80%
4	**2211**	**Electric Power Generation, Transmission and Distribution**	Zhang and Choi (2013); Zanella, Camanho, and Dias (2015); Li and Zhao (2016)	3/51 ≈5.82%
5	**3311**	**Iron and Steel Mills and Ferroalloy Manufacturing**	Singh, Murty, Gupta, and Dikshit (2007); Ma, Wen, Chen, and Wen (2014)	2/51 ≈3.92%
6	**5221**	**Depository Credit Intermediation**	Hwang, Lee, Liu, and Ouyang (2009); Mendola and Volo (2017)	2/51 ≈3.92%
7	**3121**	**Beverage Manufacturing**	Zhou, Tokos, Krajnc, and Yang (2012); Engida, Rao, Berentsen, and Oude Lansink (2018)	2/51 ≈3.92%
8	**5619**	**Other Support Services-packing**	Qalyoubi-Kemp (2009)	1/51 ≈1.96%
9	**2362**	**Non-residential Building Construction**	Kale (2009)	1/51 ≈1.96%
10	**5313**	**Activities Related to Real Estate**	Newell (2009)	1/51 ≈1.96%
11	**3344**	**Semiconductor and Other Electronic Component Manufacturing**	Wong, Ignatius, and Soh (2014)	1/51 ≈1.96%
12	**2111**	**Oil and Gas Extraction**	Bergh, Hinna, Leka, and Jain (2014)	1/51 ≈1.96%
13	**3313**	**Alumina and Aluminium Production and Processing**	Garbie (2014)	1/51 ≈1.96%

TABLE 9 CONTINUED

NO.	CODE (NAICS)	SECTOR	REFERENCES	PROPORTION
14	**5416**	**Management, Scientific, and Technical Consulting Services-logistics**	Liu, Liang, Wang, Liu, and Xie (2014)	1/51 ≈1.96%
15	**3261**	**Plastics Product Manufacturing**	Metaxas, Koulouriotis, and Spartalis (2016)	1/51 ≈1.96%
16	**3323**	**Architectural and Structural Metals Manufacturing**	Pereira, Araújo, and Costa (2018)	1/51 ≈1.96%
17	**5621**	**Waste Collection**	Rubio-Romero, Pardo-Ferreira, De la Varga-Salto, and Galindo-Reyes (2018)	1/51 ≈1.96%
18	**Multiple sectors**		Erbetta, Menozzi, Corbetta, and Fraquelli (2013); Seo and Bae (2017); Engida, Rao, Berentsen, and Oude Lansink (2018)	3/51 ≈5.88%

Note: the Proportion is calculated as the number of the references for each technique divided by 51 which is the number of total articles.

and the heavy-duty truck manufacturing sector (code: NAICS 33612). As is shown in Table 9, the current article identified seven articles with CIs in the motor-vehicle manufacturing sector, which makes this sector the most studied sector. Table 11 lists the references, the name of the CIs, the techniques used for constructing CIs, and the functions for calculating values of CIs. Each reference has its own context and aims to construct practical CIs.

Discussion

Based on the literature search and the search results, this article identifies 51 individual articles with CIs that are utilized in 17 sectors at the company level. The motor-vehicle manufacturing sector is the most studied sector. To answer RQ_1 and RQ_2 in a way that provides insight to others, this section discusses (a) the general problems that occur during CI construction and (b) the specific problems that occur during CI construction in the most studied sector.

General Problems during CI Construction

This article cites seven general problems that can occur during CI construction as follows.

Selecting variables.

This is usually done by referring to classical company-performance frameworks. However, there is a much lower rate of adoption

TABLE 10 REFERENCES DISTRIBUTION IN TERMS OF GEOGRAPHICAL AREAS

CONTINENT	COUNTRY	REFERENCE(S)	PROPORTION
Asia	**China**	Chang and Yeh (2004); Chen, Kao, Tsao, and Wu (2007); Hwang, Lee, Liu, and Ouyang (2009); Cheung, Jiang, and Tan (2010); Zhang and Choi (2013); Liu, Liang, Wang, Liu, and Xie (2014); Ma, Wen, Chen, and Wen (2014); Li and Zhao (2016); Kocmanova, Docekalova, and Simanaviciene (2017)	9/51 ≈17.65%
	India	Singh, Murty, Gupta, and Dikshit (2007); Singh, Garg, and Sharma (2010); Gopal and Thakkar (2015); Monica and Gagan (2015); Garg (2017)	5/51 ≈9.80%
	Korea	Lee, Lee, and Kang (2005); Sohn, Kim, and Moon (2007); Yoon, Kim, and Sohn, (2008); Seo and Bae (2017)	4/51 ≈7.84%
	Malaysia	Amrina and Yusof (2010); Wong, Ignatius, and Soh (2014); Wong, Ignatius, and Soh (2014)	3/51 ≈5.88%
	Turkey	Kale (2009); Ayağ and Samanlioglu (2016)	2/51 ≈3.92%
	Sultanate of Oman	Garbie (2014)	1/51 ≈1.96%
	Japan	Mendola and Volo (2017)	1/51 ≈1.96%
Europe	**The United Kingdom**	Newell (2009)	1/51 ≈1.96%
	Italy	Erbetta, Menozzi, Corbetta, and Fraquelli (2013)	1/51 ≈1.96%
	Norway	Bergh, Hinna, Leka, and Jain (2014)	1/51 ≈1.96%
	Greece	Nerantzidis (2016)	1/51 ≈1.96%
	Czech	Kocmanova, Docekalova, and Simanaviciene (2017)	1/51 ≈1.96%
America	**The United States of America**	Qalyoubi-Kemp (2009)	1/51 ≈1.96%
	Brazil	Zanella, Camanho, and Dias (2015)	1/51 ≈1.96%
Africa	**Morocco**	Chahid, El Alami, Soulhi, and El Alami (2014)	1/51 ≈1.96%
Unclear		Grimaldi and Cricelli, (2009); Focacci (2011); Zhou, Tokos, Krajnc, and Yang (2012); de Jong and Beelaerts van Blokland (2015); Harik, El Hachem, Medini, and Bernard (2015); Sahu, Sahu, and Sahu (2016); Metaxas, Koulouriotis, and Spartalis (2016); Beelaerts van Blokland, van de Koppel, Lodewijks, and Breen (2019); Azevedo, Godina, and Matias (2017); Engida, Rao, Berentsen, and Oude Lansink (2018); Pereira, Araújo, and Costa (2018)	11/51 ≈21.57%

Note: the Proportion is calculated as the number of the references for each technique divided by 51 which is the number of total articles.

TABLE 11 THE REFERENCES WITH CIS IN THE AUTOMOTIVE SECTOR

REFERENCE	NAME OF THE CI	METHOD(S)
Amrina and Yusof (2010)	An over index of suppliers	Literature review, surveys, AHP, SAW
	$Sk = \sum_{i=1}^{M} \sum_{j=1}^{Ni} WiwijRijk$, where S_k is the overall score of k supplier; W_i is the relative weight of i criterion; W_{ij} is the relative weight of j sub-criterion belonging to i criterion; R_{ijk} is rating criterion of k supplier for j sub-criterion of i criterion; M is total number of criteria; N_i is total number of sub-criterion belonging to i criterion.	
Singh, Garg, and Sharma (2010)	A leanness index	FL, Questionnaires
	$L_l(\mu) = L_A(\mu)/A + L_B(\mu)/B + L_C(\mu)/C + L_D(\mu)/D + L_E(\mu)/E + L_F(\mu)/F$, where $L_l(u)$ is the value of leanness; A, B, C, D, E, F are the crisp values from the triangular fuzzy functions $\overline{A}$ = (80,100,100), $\overline{B}$ =(60,80,100), $\overline{C}$ =(40,60,80), $\overline{D}$ =(20,40,60), $\overline{E}$ = (0,20,40), and $\overline{F}$ = (0,0,20) respectively, μ =(0,1).	
Chahid, El Alami, Soulhi, and El Alami (2014)	An overall performance index of suppliers	AHP, Performance Measurement Questionnaire, SAW
	$GP = 100 * (0.09P_{Cc} + 0.17P_{Qs} + 0.43P_{Ma} + 0.05P_{Ab} + 0.02P_{Oi} + 0.23P_{Tdb})$, where GP is the a global performance; C_c is the number of customer complaints/ one million hours delivered; Qs is (non- conformities total/ parts supplied)*1 million/ one million hours delivered; Ma is the ratio between the actual production time and the total time available; Ab is the number of hours missed/ one million hours delivered; Oi is the number of occupational injuries/ one million hours delivered; and Tdb is the average number of days of training per employee/one million hours delivered.	
Gopal and Thakkar (2015)	A sustainable supply chain performance index	AHP, FL, Liberatore score, signal-to-noise ratio and life cycle assessment polygon technique
	CSSCPI = SILS*SIS/N, where CSSCPI is composite sustainable supply chain performance index; SILS is the value from sub-index based on Liberatore score method for computing weights of qualitative indicators; and SIS/N is the value form sub-index based on signal to noise ratio method for computing weights of quantitative indicators.	
Salvado, Azevedo, Matias, and Ferreira (2015)	A sustainability index	AHP, min-max, content analysis
	$I_{C\_SUSTj} = f[W_{i1} \times (I_{i1})j, W_{i2} \times (I_{i2})j, W_{i3} \times (I_{i3})j]$, where I_{C_SUSTj} is the total sustainability index for each company; W_{i1}, W_{i2}, W_{i3} are the weights for each considered sub-index; (I_{is})j is the value of the indicator i associated to the 3 dimensions of sustainability for company j.	
Ayağ and Samanlioglu (2016)	An automotive supplier selection weighted index	ANP, FL, SAW
	$Dia = \sum_{j=1}^{J} \sum_{k=1}^{Kja} PjaA_{kja}^{D} A_{kja}^{I} S_{ikja}$, where D_{ia} is the product of the desirability index, P_{ja} is the relative importance weight of dimension j on determinant a; A_{kja}^{D} is the relative importance weight for attribute-enabler k of dimension j, and determinant a for the dependency (D) relationships between attribute-enabler's component levels; A_{kja}^{I} is the stabilized relative importance weight for attribute-enabler k of dimension j, and determinant a for the independency (I) relationships within attribute-enabler's component level; S_{ikja} is the relative impact of concept alternative i on attribute-enabler k of dimension j of concept selection network; K_{ja} is the index set of attribute-enablers for dimension j of determinant a; and J is the index set for attribute j.	

TABLE 11 CONTINUED		
REFERENCE	**NAME OF THE CI**	**METHOD(S)**
Beelaerts van Blokland, van de Koppel, Lodewijks, and Breen (2019)	A value leverage factor	Literature review, CA, SAW
	AVL = $(R_{R\&D/C \text{ versus } P/C} + R_{R\&D/C \text{ versus } R/C} + R_{P/C \text{ versus } P/C})/3$, where AVL is the vaverage R-value by a linear least squares correlation analysis between three variables, namely, turnover per capita (T/C), profit per capita (P/C) and R&D expenditure per capita (R&D/C).	

of non-financial indicators in business practice (Abdallah & Alnamri, 2015). In addition, most of the research focuses on designing a few definitions and conceptual frameworks with a holistic approach, rather than implementing by quantitative analysis for company-performance measurement.

Normalization techniques.

The techniques should be clarified since their choice might influence the choice of aggregation techniques. In addition, researchers should pay attention to the categories of the variables. However, the survey in this article finds that only 9 out of 51 articles clarified the normalization of the techniques. Only 6 out of 51 articles mentioned the categories of variables.

Weighting techniques.

This step concerns the realistic assumption that there exists preferential dependence among the variables. This means it is improper to give all variables the same weight using techniques such as EW, or to ignore the relation between variables by directly using techniques such as AHP. However, the authors' survey finds that only 14 articles considered this realistic assumption. AHP takes up the biggest mention as a solo weighting technique. This is in line with the finding that AHP ranked as the first MCDA techniques in use in 2013 (Mardani et al., 2015).

Subjectivity and imprecision.

Subjectivity and imprecision are always there during decision making (Zimmermann, 2000). In general, for weighing variables and calculating the CIs, detailed data is extracted from sample companies' annual financial reports, sustainability reports, global reporting initiative (GRI) reports, companies such as Sustainalytics, databases such as those proposed by Kinder, Lydenberg and Domini. If detailed data is unavailable, researchers need to use MCDM techniques or must totally rely on subjective scoring for weighting variables; the inherent subjectivity or ambiguous information that comes up during the weighting process should be handled.

Fuzzy logic (Klir & Yuan, 1995) can work as an effective tool to handle this problem and to provide an inference structure for relatively precise deductions. However. in this survey, there are 33 articles involving subjective judgments for weighting variables, but only 9 articles involving the adoption of fuzzy logic (Chang & Yeh, 2004; Kale, 2009; Singh, Garg, & Sharma, 2010; Gopal & Thakkar, 2015; Ayağ & Samanlioglu, 2016; Li & Zhao, 2016; Sahu, Sahu, & Sahu, 2016; Metaxas, Koulouriotis, & Spartalis, 2016; Rubio-Romero, Pardo-Ferreira, De la Varga-Salto, & Galindo-Reyes, 2018).

Aggregation techniques.

Aggregation techniques are needed for integrating individual variables into a bigger picture. Researchers should pay much attention to the assumptions of compensability between variables and the requirement for variables to be applied to specific aggregation functions. Here compensability can be defined as applying to the cases in which a poor performance in one dimension can be counterbalanced by some superior performance in other dimensions. Basically, in realistic cases there exists some degree of non-compensation between variables, which means it is improper to use a technique like SAW just because of its easy interpretation and calculation.

Non-compensatory analysis procedures.

These are required if the weights in the cases need to be interpreted as importance coefficients (Podinovskii, 1994). However, the partial or total non-compensation between variables under the realistic assumption was not considered. Eighteen of 51 articles deal with the procedure of aggregating variables, and only two articles take into account the partial compensability between variables.

Sensitivity analysis.

This has been defined as the modeler's equivalent of orthopaedists' X-rays (Joint Research Centre-European Commission, 2008), which shows its utmost importance. However, there are just two articles that have performed the post-analysis step, which indicates that very limited attention has paid to the post-analysis step of the CIs derived.

Specific Problems during CI Construction in the Motor-Vehicle Manufacturing Sector

Auto-vehicle manufacturers make profit with input on materials, resources, and energy and output on vehicles, components, and various pollutants. By the year 2016, there have been 1.2 billion cars produced, among which 2.0 million were electric cars (source: Global EV Outlook 2017). Whether they are electric cars or not, during their whole life cycle processes, the manufacturing process takes up 95% of water consumption

(Berger, Warsen, Krinke, Bach, & Finkbeiner, 2012). Furthermore, a large volume of CO_2 has been emitted, which in 2016 contributed around 72% to global greenhouse gas (source: PBL Netherlands Environmental Assessment Agency). Environmental performance is an important dimension of organizational performance (Hart, 1995). Motor-vehicle manufacturers are supposed to improve profitability along with significant environmental concerns, such as developing eco-friendly products, reducing over-consumption of energy and resources, and reducing greenhouse gas emissions.

Based on the seven general problems that can occur during CI construction discussed in the previous sub-section, this article lists nine benchmark items that are the expectations for constructing transparent, rigorous, and practical CIs for motor-vehicle manufacturers. Accordingly, the distribution of items in the seven references is shown in Table 12.

As is seen in Table 12, there are two articles focusing on CIs that include an environmental perspective. Based on a literature review and opinions from a team of three experts, Gopal and Thakkar (2015) proposed 18 sub-environmental indicators—that is, qualitative indicators (including availability of collection centers, utility utilization, implementation of environmental regulations, supplier commitment on overall environmental aspects, product to be disposed to landfill or incineration) and quantitative indicators (including total waste and percentage of suppliers having ISO Certification). Based on ISO 14031 and G4 of the Global Reporting Initiative, Salvado, Azevedo, Matias, and Ferreira

TABLE 12 THE DISTRIBUTION OF CRITERIA IN THE REFERENCES

ITEMS REFERENCE	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9
Amrina and Yusof (2010)	×	×	×	×	×	×	√	×	×
Singh, Garg, and Sharma (2010)	×	×	×	×	√	×	√	×	×
Chahid, El Alami, Soulhi, and El Alami (2014)	×	×	×	×	×	×	√	×	×
Gopal and Thakkar (2015)	√	√	√	×	√	√	√	×	×
Salvado, Azevedo, Matias, and Ferreira (2015)	√	√	√	×	×	×	×	×	×
Ayağ and Samanlioglu (2016)	×	×	×	√	√	×	√	×	×
Beelaerts van Blokland, van de Koppel, Lodewijks, and Breen (2019)	×	×	×	×	n.a.	√	√	×	×

Note:
I_1: With environmental concerns
I_2: With concerns about different categories of variables
I_3: With specific normalization technique
I_4: With concerns about preference independence between variables
I_5: With fuzzy logic/grey theory to tackle inherent subjectivity
I_6: With objective weighting techniques
I_7: With clear aggregation procedure
I_8: With concerns on compensability between variables
I_9: With post analysis step
√ means the reference satisfies the benchmark item.
× means the reference dissatisfies the benchmark item.
n.*a. means* the benchmark item is not applicable in the context of the reference.

(2015) proposed four quantitative sub-environmental indicators, including amount of non-hazardous waste, amount of hazardous waste, amount of water consumed per year in industrial processes, and amount of energy used per year. There are two articles that focus on clear normalization techniques and concerns about different categories of variables, which make their calculation more transparent and easier to understand.

There is just one article that takes into account the preference independence between variables. It adopts the ANP method, which allows dependency between factors and is more suitable for realistic problem solving as compared with AHP (Saaty, 2004). There are six articles involving subjective scoring, but only three of them deal with the adoption of fuzzy logic to handle the subjectivity and imprecision for weighting variables. There are six articles that present clear aggregation procedures, but none of them consider the compensability between variables. As to the post-analysis step, none of the seven articles conduct the SA or UA on the CIs derived.

Based on the foregoing analysis, this article summarizes two current problems in the automotive sector: (1) a lack of a relatively standard definition of company performance from an environmental perspective and (2) a lack of rigorous quantitative methods for measuring this performance. Together with the seven problems identified in the preceding subsection, this article totally identifies nine problems involved in the topic of constructing CIs at the company level.

Conclusions

Measuring company performance is challenging due to the multidimensional nature of company performance and the subjectivity and imprecision that is often involved in the decision-making process. Currently performance analysts are starting to use CIs to measure multidimensional company performance. CIs at the company level are needed for stakeholders to effectively benchmark companies' holistic performance. This article has tried to determine which CIs, utilized in sectors, are recognized in the literature.

In order to answer the research question—that is, which CIs are recognized in the literature—this article describes an up-to-date literature survey on existing CIs and identifies 51 CIs.

To answer this RQ, the authors conducted an up-to-date literature survey on existing CIs at the company level. Totally 51 CIs were identified. As to the techniques used for constructing those CIs, there are 29 specific individual techniques (listed in Figure 2) that answered the first sub-research question. As to the CIs' utilized sectors, there are 17 specific sectors, and the motor-vehicle manufacturing sector is the most studied sector (as is shown in Table 9), which answers the second sub-research question. In addition, this article has discussed seven general problems during CI construction along with three specific problems that occur during CI construction in the motor-vehicle manufacturing sector.

There are some literature studies on CIs: (Asadzadeh, Kötter, Salehi, & Birkmann, 2017; Greco, Ishizaka, Tasiou, & Torrisi, 2019; Mori & Christodoulou, 2012). However, these are focused on macro levels. Unlike those studies which are inappropriate for implementation at the company level, the literature survey in this article contributes to both academics and practitioners. It presents academics with an up-to-date overview of current CIs at the company level, their applications, and the techniques used. The discussion in each of the corresponding steps can be a helpful guide for developing a scientific approach for constructing original CIs. Furthermore, it focuses on practitioners from specific sectors dealing with CIs' practical applications in companies. This can generate a more transparent implementation during the CI construction process as well as a better understanding about how CIs work in monitoring or benchmarking company performance. Both the transparent implementation and the better understanding can serve as effective tools for practitioners to use to make decisions.

The choice to use fewer keywords hardly influences the search results. With fewer keywords, more than 56469 potential articles can be obtained after step one. However, double-checking by step two, the number of final identified articles can be stated as 51 because of the three exclusion criteria. In other words, despite the existence of more potential articles after step one, more ineligible articles can be excluded by the three exclusion criteria.

The choice of the inclusion criteria influences the search results. This article exclusively includes articles from three sources. This probably leads to the loss of some eligible publications, such as conference papers or articles from other sources. This shortcoming which is associated with the literature-search strategy is the first research limitation in this article. The other limitation is that this article exclusively focuses on CIs at the company level. In terms of the techniques used for constructing the CIs, it is likely that this article misses other potential techniques that have been applied in CIs at other levels but can be used for constructing CIs at the company level as well.

Based on the findings and the limitations in this article, four recommendations are provided for further research, listed as follows:

1. It is necessary and can be interesting to concentrate more on the post-analysis for the CIs, which can help gauge the robustness of the CI and improve its transparency.
2. In line with the statement by Abdallah and Alnamri, 2015, the authors have observed that there is a much lower rate of adoption of non-financial indicators in business practice. It is suggested to define and measure company performance from an environmental perspective.
3. A more relevant literature-survey strategy should be conducted, extending the publication types and including broader database.
4. There are various unpredictable issues involved in constructing CIs for companies, such as those relevant to financial crises. In that

case, it can be interesting to predict how the CIs contribute as a method to predict the trend of the global economy, which has not been discussed as of now.

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