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A DEMATEL method for identifying supply chain complexity drivers of footwear industry

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A B S T R A C T

This study aims to investigate the key drivers of supply chain complexity in the footwear industry business sector. After conducting extensive literature review and consultation with experts, complexity drivers in the context of the footwear business sector were identified. The content validity of the identified drivers was checked by 13 experts using content validity ratio (CVR), which were used as the basis to select 20 key Supply Chain complexity drivers. Using a multi-criteria decision-making DEMATEL approach the cause and effect drivers were investigated. The findings of the study investigated 12 cause and 8 effect drivers in the footwear sector. Among the cause drivers, four linkage drivers that have strong driving power and dependency were identified. This study is the first in the developing county footwear business sector using DEMATEL approach to identify the key supply chain complexity drivers and their interrelationship. The study identified complexity drivers in the context of the footwear business sector that were not explored before in the existing studies. The outcome of this study will help SC complexity decision-makers in that case sector to control and manage the cause and effect drivers and thus improve the efficiency and effectiveness of their SC performance.

1. Introduction

In the areas of management like supply chain decision making plays a crucial role for the improvement of the system performance. Nowadays, due to disruption and technological advancements, introduction of new products/services to the system, globalization, global geopolitical risk, innovation, flexibility, adoption of new technologies and mass-customization interactions interdependencies within SC system growth rapidly (Deloitte,2003). An increased complexity within the network raises the cost of the supply chain (Serdarasan, 2013) and disrupts the supply chain (Bode and Wagner, 2015). This problem comes from a variety of internal and/or external driving causes, and it happens in the upstream, midstream, and downstream SC network. Existing studies investigated the types of drivers that cause and increase complexities within the SC network. According to, Kavilal et al. (2018), SCC of the passenger vehicle sector is increased by the number of suppliers, product life cycle and demand uncertainties. On the other hand, the SCC of commercial vehicle sectors increased due to the number of parts, products and processes, variety of products and processes and unreliability of suppliers. In mining equipment manufacturer industries, the unreliability of suppliers, forecast inaccuracy, lack of visibility and information sharing, and the number and variety of processes are the significant drivers that cause supply chain complexity (Kavilal et al., 2017). The degree of detailed and dynamic complexity brought about by the number and variety of product and processes in SC (Bozarth et al., 2009) is one example of the drivers of SCC. To prioritize and identify the key drivers, Chand et al. (2018) selected 23 supply chain complexity drivers from literature review and in consultation with experts from mining equipment manufacturing companies in India. And their findings indicated that supplier resourcing risk, supplier competence, regional strategies, shortening product life-cycle, changing customer service expectation as key a diver that makes SC complexity. Through a case study in the automotive industry, Kavilal et al. (2016) determined that supplier unreliability,

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market risk and uncertainty, customer needs that change, and inaccurate forecasts are the main drivers of supply chain complexity. On the other hand, Piya et al. (2020) investigated the highest dominance drivers responsible for FMCG companies supply chain as customer need, competitor action, and government regulations.
Due to the nature of drivers and proposed approach is based on the opinion of the experts and it makes it biased, identifying and developing industry specific criteria, complexity driver's types and proposing decision making approach should be needed (Kavilal et al., 2017). Based on the nature or dynamics of the industry the number of SCC drivers may increase, decrease, or be rationalized. Similarly, the level of complexity and relevance of identified drivers on SC vary depending on the industry and environment in which it operates. As such, the management's attitude towards that drive to mitigate its impact on SC may also differ (Piya et al., 2020). Varying SCC drivers have different effects on determining the SCC level from sector to sector. Based on this, in their study, they suggested that the proposed other studies should be needed by identifying industry-specific SCC drivers (Kavilal et al., 2018). In addition, due to geographical location, cultural difference between countries and industries, uniqueness of process and working conditions, uniqueness of elements within Supply Chain network, etc., SCC drivers vary from country to country and industry to industry. Among different industries, the footwear Supply Chain is more complex than others because of their large number of raw materials used, number and variety of suppliers, customer heterogeneity, number of production processes, etc.

This indicates that identifying, prioritizing and analyzing SCC drivers based on the types of industries plays a vital role in improving Supply Chain efficiency and performance. In this regard, different researches have been carried out in the past to identify and analyze the SCC drivers. However, those researches did not explicitly distinguish and analyze the identified drivers based on the types of industry and production strategy the company uses. In addition, no studies were found in analyzing and identifying the critical drivers that increase SCC in the case of the footwear industry, especially in developing countries like Ethiopia. Thus, this study is intended to fill these gaps and will answer the following questions.

1. What are the key supply chain complexity drivers in the footwear industry?
2. Which of the drivers are vital in increasing the complexity of the footwear industry supply chain network?
3. What are the interactions and connections between the identified supply chain complexity drivers in the footwear industry?

2. Literature Review

2.1 Supply chain complexity and its classification

As observed from the literature, there are diverse forms of supply chain complexity classifications based on different contests. For instance, the paper by Choi and Krause (2006), states that complex systems are made up of many different kinds of subsystems that interact with one another. Conversely, Serdarasan (2013) and Bozarth et al. (2009) looked at system complexity from both a static and dynamic standpoint. The complex nature of the SC system (network) was conceptualized differently in the studies that are now available. For instance, SCC was conceptualized by Jacobs and Swink (2011) in terms of the SC system's constituents' of multiplicity, diversity, and interdependence. They define multiplicity as a system's abundance of constituent parts. However, from the multiplicity point of view, Bozarth et al. (2009), Choi and Krause (2006) conceptualized SCC in terms of the quantity of suppliers, customers, and goods that make up or symbolize a company's network of relationships. From an interrelatedness perspective, however, complexity has been defined as the level of interaction between system components.

SCC is defined as the level of details (static) and dynamic complexity exhibited by the products, processes and relationships that make up a SC (Bozarth et al., 2009). Detail (static) complexity refers to "the distinct number of components or parts that make up a system" (akin to structural complexity in the project domain). Details SCC is determined by the quantity and variety of products, processes, customers, and suppliers (Vachon & Klassen, 2002; Bozarth et al., 2009; Serdarasan, 2013). It is also correlated with the SC's structure (Vachon & Klassen, 2002) or with the quantity and variety of components (such as the supply base, product types, and markets served) within the supply chain (Cheng et al., 2014). However, dynamic complexity also known as operational complexity, according to Wu et al., (2007) and Bozarth et al. (2009) reflects "the unpredictable nature of a system's reaction to a given set of inputs, partially attributed to the interconnectivity of numerous system components". It has to do with time and randomness uncertainties (Serdarasan, 2013) and ambivalence and ambiguity (Isik, 2010) in processes, demand, and/or the geopolitical context, among other things. On the other hand, the main findings of the review paper by Abbasi and Varga (2022) illustrated that complexity property of SC are categorized in to four, which are (1) Structural complexity, (2) Dynamic complexity, (3) Behavioral complexity and (4) Decision making complexity. Wilson and Perumal (2009) in their book chapter divided SCC into organizational complexity, product complexity, and process complexity. According to them organizational complexity consists of the various facilities, groups, and systems that operate a company's processes. While, product complexity indicates the diversity of products offered to customers, and process complexity refers to the range of business processes and business contact points utilized in providing a product and its support. The paper by Hendryk et al. (2018) tried to investigate the interaction between SCC by classifying it into detail and dynamic, and according to its origin or source into plant, supply chain and environment. Seyda (2013) in his reviewed paper used three types of SCC like (1) static, (2) dynamic and (3) decision making to investigate their drivers.

And it is classified according to its origin into internal, supply/demand interface and external. Bugra and Robert (2019) in their study considered Structural complexity and expressed it as the combination of both inherent complexity of system entities and topological complexity resulting from the integration of elements of such constellations in a multi-layered network. Furthermore, the research by Iman et al. (2015) divided and utilized SCC into three categories according to their location: (a) Upstream complexity, (b) internal manufacturing complexity, and (c) Downstream complexity. Similarly, Cecil et al. (2009) classified complexities of SC based on their origin into downstream complexity, Internal manufacturing complexity and upstream complexity. The conference paper by Blecker et al. (2005) used a two-dimensional approach to identify the types of complexity drivers and their point of origin. And they classified the major complexity causing areas according to the origin of drivers into three sections: (1) Internal organization, (2) Supplier-customer interface and (3) Dynamic environment.

2.2. Supply chain complexity drivers and their effects

Supply chain complexity drivers are any properties of a SC that increases its complexity (interconnectedness and interdependence between supply chain entities). According to prior studies there are different types of drivers that make supply chains complex. Thus, the types of drivers, their sources and origins are reviewed in this part of the paper.

The study by Kavilal et al. (2018) identified 18 SCC drivers from the literature and they classified them into four dimensions as: (1) Numerousness, (2) Variability, (3) Diversity, and (4) Uncertainty. And their result indicated that various SCC drivers have different impacts on determining the SCC level from sector to sector. In addition, according to Kavilal et al. (2018) number of suppliers, increase in spare-parts due to shortened product life-cycle and demand uncertainties increase the SCC of the passenger vehicle sector, but number of parts, products and processes, variety of products and processes and unreliability of suppliers increase the complexity of the commercial vehicle sector. Piya et al. (2019) identified twenty-three drivers responsible for SCC.

The study by Chhetri et al. (2021) developed integrated theoretical framework to empirically test the linkage between product demand and design characteristics of SCC. Their results indicated that SCC is directly impacted by volatility of demand, product life cycle, and innovativeness. In addition, product demand and design characteristics increase complexity in SC. The study by Cecil et al. (2019) used twelve measures of supply chain complexity to assess its impact on organizational performance. The results of their hypothesis test indicated that upstream complexity, internal manufacturing complexity, and downstream complexity all have a negative impact on manufacturing plant performance. In addition, supply chain characteristics that drive dynamic complexity are shown to have a greater impact on performance than those that drive only detail complexity. Chand et al. (2018) investigated drivers like supplier resourcing risk, supplier competence, regional strategies, shortening product life-cycle, changing customer service expectation that increases supply chain complexity. Filiz (2010) in his study identified and measured structural and operational complexity associated with information and material flows in the supply chain. Alkan and Harrison (2019) express structural complexity in terms of inherent complexity of system entities and topological complexity which is resulted from the integration of elements of such constellations in a multi-layered network. On the other hand, Seyoum et al. (2017) on their study focused on supply chain Structural complexity like, product portfolio, supply base dispersion, size and restructuring to investigate its impact on resilience capability and performance.

The study by de Leeuw et al. (2013) identified eight drivers of SCC and they use these drivers to illustrate the measurement of supply chain complexity in a wholesale environment. And their findings show the important features of SCC elements. According to Gerschberger et al. (2012) complexity is determined by five generic core parameters such as: (1) the number of elements and interrelations that define the system, (2) the degree of uncertainty that enters the system, (3) the influence of the supplier on the customer, (4) the requested product variety and (5) the geographical components that act on the system. Iman et al. (2015) in their study investigated the impacts of SCC competitiveness capability using twelve types of dynamic complexity drivers that occurred in upstream, downstream and internal manufacturing complexity. According to Stock et al., (2000), organizational complexity is caused due to geographical span of suppliers and the number of echelons in the supply chain. Bugra and Robert (2019) identified structural complexity drivers that cause ever-growing complexity of manufacturing systems as- technological advancements, uncertain global market and mass personalization. Choi and Krause, D. R. (2006) in their study, supply base complexity (upstream supply chain complexity) is conceived in three dimensions: (a) the number of suppliers in the supply base, (b) the degree of differentiation among these suppliers and (c) the level of inter-relationships among the suppliers. Thus, based on an extensive literature review conducted by this paper, supply chain complexity drivers found in the existing studies were identified and summarized in Table 1.

Table 1
List of supply chain complexity drivers

Drivers	References
Upstream supply chain complexity drivers	
Number of suppliers	Piya et al. (2020), Hendryk et al.(2018); Seyda, (2013), Cecil et al. (2019), Kavilal et al.(2018), Choi and Krause (2006)
Variety of suppliers	Hendryk et al., (2018), Seyda (2013)
Supplier location	Sujan et al.(2019)
Percentage of purchases imported, Supplier delivery unreliability	Cecil et al. (2019)
Supplier resourcing risk, Supplier competence	Chand et al. (2018)
Supplier reliability	Blecker et al. (2005)
Supply variability	Hendryk et al., (2018)
Degree of differentiation among suppliers, the level of inter-relationships among the suppliers	Choi and Krause (2006)
Number of interactions with the suppliers	Bozarth et al. (2009)
Geographical span of suppliers	Stock et al. (2000)
Unreliability of suppliers (reliability on the suppliers)	Bozarth et al. (2009), Kavilal et al. (2018)
Midstream supply chain complexity	
Number of parts, number of warehouses	Kavilal et al.,(2018)
Number of products	Hendryk et al., (2018), Seyda, (2013), Cecil et al. (2019), Kavilal et al. (2018)
Number of processes	Hendryk et al.(2018),Seyda, (2013), Kavilal et al. (2018)
Number of Connections	Bozarth et al. (2009), Kavilal et al. (2018)
Variety of products (product Varity)	Piya et al. (2020), Hendryk et al.(2018), Seyda, (2013), Kavilal et al.(2018), Chhetri et al. (2021),
Variety of processes (manufacturing process)	Piya et al. (2020), Hendryk et al.(2018), Seyda, (2013), Kavilal et al. (2018)
Product development (new product development)	Piya et al. (2020)
Types of product, Process interactions	Hendryk et al. (2018), Seyda (2013)
Product modularity, Product innovativeness, Product structure complexity	Chhetri et al. (2021)
Manufacturing schedule instability, Number of active parts	Cecil et al. (2019)
The stability of industrial scheduling, Time that should be waited before the delivery (delivery lead time), Number of sections, Number of covered products, Various industrial processes	Bozarth et al. (2009)
Forecast inaccuracy	Kavilal et al. (2018), Chand et al. (2018)
Process uncertainties, Employee related uncertainties, Unhealthy forecasts/plans, Lack of process synchronization	Seyda (2013), Chand et al. (2018)
Number of product lines	Seyoum et al., (2017)
(Lack of) Control over processes, Ability to forecast/plan, Manufacturing schedule instability, One of a kind/low volume batch production, Employee induced variability	Hendryk et al., (2018)
Technological advancements, Mass personalization	Bugra and Robert (2019)
Product life-cycle (Short product life cycle) (globalization shortened product lifecycle)	Bozarth et al. (2009), Piya et al. (2020), Hendryk et al., (2018), Seyda, (2013), Cecil et al. (2019), Blecker et al. (2005), Kavilal et al. (2018), Chhetri et al.(2021), Chand et al. (2018)
Technological Innovation (change) (new technology)	Piya et al. (2020), Hendryk et al.(2018), Seyda, (2013), Blecker et al. (2005), Kavilal et al. (2018)
Organizational standards	Piya et al. (2020)
Improper process synchronization (Process synchronization)	Piya et al. (2020), Hendryk et al. (2018)
Raising product complexity, Changing technological, Non-harmonized processes, Process-related deficits, Changing skill requirements	Blecker et al. (2005)
Number and geographical dispersion of production facilities and legal entities, Variety of product lines, Number of brands, Variety of brands, Turnover of employees, Number of employees	Seyoum et al.(2017)
Downstream supply chain complexity drivers	
Number of customers	Piya et al. (2020), Hendryk et al.(2018), Seyda, (2013), Cecil et al. (2019), Kavilal et al. (2018)
Variety of customers, changing needs of customers, trends in the market	Hendryk et al.(2018), Seyda (2013)
Customer heterogeneity, long supplier lead times (supplier lead time)	Cecil et al. (2019)
Demand uncertainty	Chhetri et al. (2021)
Demand variability	Bozarth et al.(2009), Hendryk et al.(2018), Cecil et al. (2019)
Changing customer service expectation, Market uncertainty and risk, Constant change in customer requirement, Multiplicity of customers	Chand et al. (2018)
Demand amplification, Market uncertainties	Seyda (2013)
Heterogeneous demands, Customer reliability, demand amplification (bullwhip), changing in customer demands	Blecker et al. (2005)
Heterogeneity of customers' needs	Bozarth et al. (2009)
Changing needs of customers (Customer need)	Piya et al. (2020), Kavilal et al. (2018)

3. Methodology

3.1 Research procedure

Fig. 1 shows the research procedure developed by this study. As part of the study, an extensive literature review was conducted to identify supply chain complexity drivers and the identified items were developed using 1-3 scale (1= as essential, 2= important but not essential, 3= not necessary). Experts from footwear industries were invited to give their opinion or judgments on the identified drivers based on the ratings given. The steps in content validity and DEMATEL model have been applied. Content validation was conducted to identify the relevant drivers based on the responses of the experts. Using the retained item from the outcome of content validity result, contextual relationships were developed in consultation with experts. Finally, from the developed contextual relationship cause and effect drivers were identified.

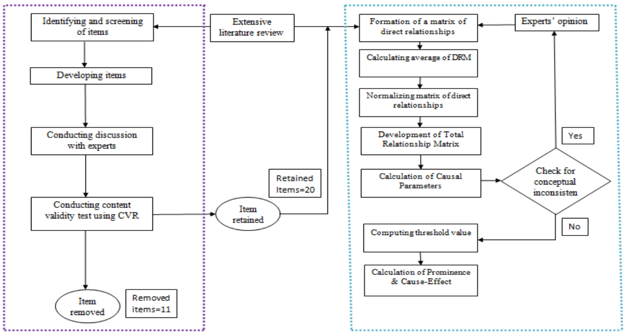

Fig. 1. Overview of research procedure

3.1.1 Content validity of the constructs

According to Yusoff (2019), content validity refers to how well a measurement tool captures the construct being tested. It is seen as crucial proof that a measurement tool, such a research questionnaire, is legitimate. Content validation should be carried out methodically based on the available data and industry best practices, since it is essential to ensuring overall authenticity. Based on best practices and available data, this study outlines a methodical way to measure content validity of the identified items using CVR and CVI indexes as shown in Eq. (1). The equations for CVR and CVI are given below:

$$CVR = \frac{\left(Ne - \frac{N}{2}\right)}{\left(\frac{N}{2}\right)} \quad \text{and} \quad \mathrm{CVI} = \sum\nolimits_{n}^{1} \frac{\mathrm{CVR}}{\text{retained items}} \tag{1}$$

where, Ne= the number of experts indicating "essential" and N = the total number of experts.

3.1.2 DEMATEL procedures

Step 1: Formation of a matrix of direct relationships (DRM) (e)

Using the linguistic scale, n drivers and L footwear industry experts have shared their opinions regarding the relationships and level of correlation between the drivers. In this study five degrees of influence are used as shown in Table 2.

Table 2
Five levels of influence

The influence of a driver on another	Related number
No influence	0
Low influence	1
Medium influence	2
High influence	3
Very high influence	4

After collecting all of the expert's responses, the (n × n) matrix for individual expert is create using the Mathematical formulation shown in Eq. (1).

$$e = \begin{pmatrix} 0 & e_{12} & . & e_{1(n-1)} & e_{1n} \\ e_{21} & 0 & . & e_{2(n-1)} & e_{2n} \\ . & . & 0 & . & . \\ . & . & . & 0 & . \\ e_{(n-1)1} & e_{(n-1)2} & . & . & e_{(n-1)n} \\ e_{n1} & e_{n2} & . & e_{n(n-1)} & 0 \end{pmatrix} \tag{2}$$

Step 2: Calculating average of DRM (a)

After forming a direct relationship matrix (e) as shown in Eq. (2) for individual 13 experts, the average direct relationship matrix (a) was developed using Eq. (3).

$$a = \frac{1}{L}\sum_{L=1}^{n} e_{ij} \tag{3}$$

$$\mathrm{g} = \frac{1}{Max\ 1 \le i \le n\ \sum_{j=1}^{n} e_{ij}} \tag{4}$$

Step 3: Normalizing matrix of direct relationships (H)

Normalized DRM (H) was obtained by multiplying equation 3 and 4 (a × g)

Step 4: Calculate or Development of Total Relationship Matrix (S)

$$S = H\,(I-1)^{-1} \tag{5}$$

where I is n×n identity matrix

Step 5: Obtain sum of raw and column or Calculation of Causal Parameters

Eq. (5) and Eq. (6) were used to obtain the sum of raw and column from the total relationship matrix.

$$\mathrm{SR} = \sum_{i=1}^{n} e_{ij} \tag{6}$$

$$\mathrm{SC} = \sum_{j=1}^{n} e_{ij} \tag{7}$$

Step 6: Computing threshold value (α)

By utilizing Eq. (8), the threshold value (α) is calculated by averaging the components in matrix T. With this computation, the elements with values less than threshold value are removed while conducting (drawing) cause effect diagram.

$$\alpha = \frac{\sum_{i=1}^{n}(e_{ij})\sum_{j=1}^{n}(e_{ij})}{N} \tag{8}$$

where N is the total number of elements in the matrix T

Step 7: Obtaining or Calculation of Prominence & Cause-Effect

Cause-effect is computed by subtracting SC from SR, whereas prominence is computed by adding the causal parameters SR and SC. It is said that the cause component is positive SR-SC and the impact component is negative SR-SC.

4. Results and Discussions

4.1 Content validity test results

For calculating CVR values for each driver or items Lawsh CVR worksheets excel was used and the results of this study were summarized in Table 3. Based on this the findings in Table 3 indicated that all the drivers obtained positive CVR value ranges from 0.625 to 1, which fulfills the minimum value of CVR, which is 0.49 as recommended by Creswell and Shekharan and Bougie. This result revealed that the identified drivers from literature review and Experts opinion were correctly identified and explains supply chain complexities.

Table 3
Content validity test results

Types of complexity	Drivers and coding	CVR-value
Upstream supply chain complexity	Number of suppliers (**VR1**)	0.625
	Variety of suppliers (**VR2**)	0.875
	Geographic span of suppliers (**VR3**)	0.875
	Suppliers' reliability **(VR4)**	0.875
Midstream supply chain complexity	Variety of products **(VR5)**	0.625
	Number of products **(VR6)**	0.875
	Variety of manufacturing process **(VR7)**	0.75
	Number of processes **(VR8)**	0.75
	Processes interactions **(VR9)**	0.875
	Forecasting inaccuracy **(VR10)**	0.75
	Technological innovation **(VR11)**	1
	Process (manufacturing) uncertainty **(VR12)**	0.75
	Employee induced variability **(VR13)**	1
Downstream supply chain complexity	Number of customers **(VR14)**	0.961
	Variety of customers **(VR15)**	0.782
	Changing need in customer demands **(VR16)**	0.812
	Demand variability **(VR17)**	0.743
	Trends in the market **(VR18)**	0.824
	Market uncertainty and risk **(VR19)**	0.673
	Heterogeneous demand **(VR20)**	0.936

4.2 Conducting DEMATEL analysis

In this study, the interrelationship between the identified twenty complexity drivers is explored by using the DEMATEL approach. The results obtain by using Eq. (2) to Eq. (8) were illustrated from Table 4 to 6. From total relationship matrix cause and effect relationship of the drivers were calculated and the results are illustrated in Table 7 and Fig. 3**.**

Table 4
Direct relationship matrix (Average)

	VR1	VR2	VR3	VR4	VR5	VR6	VR7	VR8	VR9	VR10	VR11	VR12	VR13	VR14	VR15	VR16	VR17	VR18	VR19	VR20
VR1	0.000	0.154	0.077	1.154	1.769	1.462	0.077	0.231	0.000	1.846	0.077	0.154	0.000	1.769	0.000	0.077	0.000	1.000	0.000	0.000
VR2	2.692	0.000	0.077	2.385	0.308	1.615	0.154	0.077	0.154	1.000	0.000	0.000	0.077	0.000	2.538	0.000	1.692	0.000	0.846	0.000
VR3	0.077	0.846	0.000	1.077	0.000	0.000	0.231	0.154	0.000	2.769	0.846	0.000	0.000	1.769	0.000	0.000	0.846	0.923	0.000	0.000
VR4	1.692	2.615	0.923	0.000	2.923	2.000	1.462	0.692	0.154	2.231	0.000	1.846	1.615	0.846	0.000	0.000	1.769	0.000	0.077	0.077
VR5	2.769	2.692	0.231	1.538	0.000	2.231	2.923	2.308	3.000	1.308	0.846	0.923	0.077	0.000	1.769	0.000	0.000	1.692	0.923	0.000
VR6	3.154	0.923	2.000	0.000	1.538	0.000	2.462	2.538	1.615	2.692	0.000	1.769	0.769	2.385	1.769	0.000	0.000	0.846	0.000	0.077
VR7	0.000	0.077	0.385	0.000	1.692	2.231	0.000	0.308	0.846	2.385	0.000	1.538	0.154	0.077	0.077	0.308	0.000	0.077	0.000	0.000
VR8	0.000	0.231	0.308	0.769	1.615	2.154	0.154	0.000	3.231	2.538	1.538	0.769	1.615	2.308	0.923	1.000	0.769	0.000	0.846	0.846
VR9	0.000	0.000	0.231	0.231	2.538	2.923	0.154	1.385	0.000	1.615	1.692	1.615	1.615	1.692	0.846	1.692	1.692	0.846	1.692	0.692
VR10	3.385	2.538	0.308	1.615	0.846	3.154	0.231	0.000	0.077	0.000	0.000	3.385	2.615	1.692	1.692	2.538	3.385	0.000	2.538	0.000
VR11	2.077	0.846	1.692	0.000	1.692	2.538	2.615	2.538	1.692	0.000	0.000	0.000	0.846	1.769	0.846	0.000	0.077	0.077	0.000	0.000
VR12	1.769	1.846	0.000	2.538	2.923	3.231	0.308	0.923	1.769	2.308	0.231	0.000	0.923	1.846	2.538	1.692	2.692	1.615	0.846	1.769
VR13	0.077	0.077	0.077	0.000	1.000	1.615	0.000	0.077	0.231	1.692	0.154	0.769	0.000	0.000	0.077	0.000	0.846	0.000	0.000	0.000
VR14	0.923	2.692	0.923	3.077	2.077	2.769	2.385	1.385	1.077	1.231	0.231	0.923	1.077	0.000	1.692	1.385	1.692	0.000	1.769	0.846
VR15	1.769	2.538	1.000	1.538	2.231	2.000	2.077	2.231	1.000	2.538	0.692	1.077	0.000	0.077	0.077	0.077	1.615	0.000	1.692	0.000
VR16	3.385	2.692	0.000	0.154	2.846	2.308	0.154	0.308	0.154	1.462	0.308	1.462	2.077	0.000	0.231	0.000	0.769	1.692	2.615	0.846
VR17	1.846	2.538	0.846	0.077	2.231	1.538	0.846	0.000	0.231	2.077	0.077	0.923	1.615	0.000	0.000	0.923	0.000	2.615	0.846	1.692
VR18	0.923	1.692	0.000	1.692	2.154	1.769	0.231	0.923	0.154	1.462	0.077	1.615	0.154	1.000	1.538	0.077	0.000	0.000	2.615	0.923
VR19	2.692	3.385	0.000	2.462	2.692	2.385	0.769	0.000	0.692	2.077	0.615	2.154	0.692	1.538	2.308	2.308	1.692	1.538	0.000	1.615
VR20	2.615	2.692	0.000	0.846	2.538	1.692	1.846	0.000	0.846	1.692	0.000	0.769	0.846	0.000	0.077	0.000	0.846	0.769	0.000	0.000

Table 5
Normalized relationship matrix (H)

	VR1	VR2	VR3	VR4	VR5	VR6	VR7	VR8	VR9	VR10	VR11	VR12	VR13	VR14	VR15	VR16	VR17	VR18	VR19	VR20
VR1	0.000	0.004	0.002	0.029	0.045	0.037	0.002	0.006	0.000	0.047	0.002	0.004	0.000	0.045	0.000	0.002	0.000	0.025	0.000	0.000
VR2	0.068	0.000	0.002	0.060	0.008	0.041	0.004	0.002	0.004	0.025	0.000	0.000	0.002	0.000	0.064	0.000	0.043	0.000	0.021	0.000
VR3	0.002	0.021	0.000	0.027	0.000	0.000	0.006	0.004	0.000	0.070	0.021	0.000	0.000	0.045	0.000	0.000	0.021	0.023	0.000	0.000
VR4	0.043	0.066	0.023	0.000	0.074	0.050	0.037	0.017	0.004	0.056	0.000	0.047	0.041	0.021	0.000	0.000	0.045	0.000	0.002	0.002
VR5	0.070	0.068	0.006	0.039	0.000	0.056	0.074	0.058	0.076	0.033	0.021	0.023	0.002	0.000	0.045	0.000	0.000	0.043	0.023	0.000
VR6	0.080	0.023	0.050	0.000	0.039	0.000	0.062	0.064	0.041	0.068	0.000	0.045	0.019	0.060	0.045	0.000	0.000	0.021	0.000	0.002
VR7	0.000	0.002	0.010	0.000	0.043	0.056	0.000	0.008	0.021	0.060	0.000	0.039	0.004	0.002	0.002	0.008	0.000	0.002	0.000	0.000
VR8	0.000	0.006	0.008	0.019	0.041	0.054	0.004	0.000	0.082	0.064	0.039	0.019	0.041	0.058	0.023	0.025	0.019	0.000	0.021	0.021
VR9	0.000	0.000	0.006	0.006	0.064	0.074	0.004	0.035	0.000	0.041	0.043	0.041	0.041	0.043	0.021	0.043	0.043	0.021	0.043	0.017
VR10	0.085	0.064	0.008	0.041	0.021	0.080	0.006	0.000	0.002	0.000	0.000	0.085	0.066	0.043	0.043	0.064	0.085	0.000	0.064	0.000
VR11	0.052	0.021	0.043	0.000	0.043	0.064	0.066	0.064	0.043	0.000	0.000	0.000	0.021	0.045	0.021	0.000	0.002	0.002	0.000	0.000
VR12	0.045	0.047	0.000	0.064	0.074	0.082	0.008	0.023	0.045	0.058	0.006	0.000	0.023	0.047	0.064	0.043	0.068	0.041	0.021	0.045
VR13	0.002	0.002	0.002	0.000	0.025	0.041	0.000	0.002	0.006	0.043	0.004	0.019	0.000	0.000	0.002	0.000	0.021	0.000	0.000	0.000
VR14	0.023	0.068	0.023	0.078	0.052	0.070	0.060	0.035	0.027	0.031	0.006	0.023	0.027	0.000	0.043	0.035	0.043	0.000	0.045	0.021
VR15	0.045	0.064	0.025	0.039	0.056	0.050	0.052	0.056	0.025	0.064	0.017	0.027	0.000	0.002	0.002	0.002	0.041	0.000	0.043	0.000
VR16	0.085	0.068	0.000	0.004	0.072	0.058	0.004	0.008	0.004	0.037	0.008	0.037	0.052	0.000	0.006	0.000	0.019	0.043	0.066	0.021
VR17	0.047	0.064	0.021	0.002	0.056	0.039	0.021	0.000	0.006	0.052	0.002	0.023	0.041	0.000	0.000	0.023	0.000	0.066	0.021	0.043
VR18	0.023	0.043	0.000	0.043	0.054	0.045	0.006	0.023	0.004	0.037	0.002	0.041	0.004	0.025	0.039	0.002	0.000	0.000	0.066	0.023
VR19	0.068	0.085	0.000	0.062	0.068	0.060	0.019	0.000	0.017	0.052	0.016	0.054	0.017	0.039	0.058	0.058	0.043	0.039	0.000	0.041
VR20	0.066	0.068	0.000	0.021	0.064	0.043	0.047	0.000	0.021	0.043	0.000	0.019	0.021	0.000	0.002	0.000	0.021	0.019	0.000	0.000

Table 6
Total relationship matrix (S)

	VR1	VR2	VR3	VR4	VR5	VR6	VR7	VR8	VR9	VR10	VR11	VR12	VR13	VR14	VR15	VR16	VR17	VR18	VR19	VR20
VR1	0.028	0.030	0.010	0.047	0.068	0.066	0.020	0.021	0.015	0.071	0.006	0.024	0.014	0.059	0.018	0.012	0.017	0.034	0.015	0.006
VR2	0.100	0.031	0.013	0.079	0.041	0.075	0.024	0.018	0.018	0.060	0.005	0.023	0.017	0.019	0.080	0.011	0.062	0.014	0.036	0.007
VR3	0.028	0.045	0.008	0.045	0.023	0.029	0.020	0.014	0.010	0.090	0.024	0.019	0.015	0.057	0.016	0.011	0.040	0.031	0.015	0.006
VR4	0.091	0.106	0.036	0.033	0.115	0.104	0.063	0.040	0.030	0.104	0.008	0.077	0.063	0.048	0.032	0.018	0.074	0.021	0.025	0.013
VR5	0.121	0.110	0.023	0.074	0.058	0.122	0.103	0.087	0.105	0.093	0.034	0.063	0.029	0.037	0.080	0.022	0.035	0.062	0.052	0.013
VR6	0.127	0.070	0.064	0.040	0.092	0.067	0.091	0.090	0.071	0.126	0.014	0.082	0.046	0.094	0.079	0.024	0.038	0.041	0.031	0.015
VR7	0.031	0.027	0.018	0.018	0.067	0.087	0.016	0.024	0.037	0.086	0.006	0.059	0.019	0.020	0.022	0.020	0.019	0.014	0.016	0.007
VR8	0.055	0.055	0.025	0.053	0.094	0.118	0.038	0.031	0.109	0.115	0.051	0.058	0.070	0.089	0.057	0.048	0.055	0.022	0.051	0.035
VR9	0.062	0.056	0.024	0.043	0.121	0.139	0.041	0.067	0.034	0.098	0.054	0.080	0.070	0.076	0.059	0.065	0.076	0.047	0.073	0.034
VR10	0.158	0.129	0.028	0.088	0.094	0.157	0.045	0.033	0.035	0.075	0.011	0.129	0.099	0.080	0.087	0.089	0.128	0.035	0.097	0.021
VR11	0.086	0.051	0.056	0.025	0.081	0.110	0.090	0.087	0.069	0.047	0.011	0.027	0.040	0.071	0.046	0.014	0.024	0.017	0.019	0.009
VR12	0.124	0.119	0.023	0.112	0.149	0.166	0.055	0.063	0.083	0.135	0.021	0.054	0.062	0.087	0.110	0.069	0.113	0.073	0.063	0.063
VR13	0.023	0.019	0.008	0.011	0.041	0.060	0.011	0.012	0.016	0.060	0.007	0.033	0.010	0.012	0.015	0.008	0.033	0.009	0.010	0.005
VR14	0.090	0.126	0.042	0.116	0.116	0.142	0.097	0.066	0.060	0.100	0.019	0.068	0.059	0.036	0.082	0.057	0.082	0.027	0.075	0.037
VR15	0.102	0.112	0.041	0.075	0.109	0.115	0.083	0.083	0.056	0.122	0.029	0.067	0.029	0.037	0.039	0.025	0.076	0.024	0.069	0.014
VR16	0.142	0.115	0.013	0.043	0.122	0.118	0.034	0.034	0.032	0.091	0.017	0.072	0.074	0.032	0.044	0.019	0.051	0.066	0.091	0.035
VR17	0.096	0.105	0.032	0.035	0.099	0.091	0.046	0.021	0.028	0.098	0.009	0.055	0.061	0.026	0.032	0.039	0.028	0.085	0.046	0.053
VR18	0.076	0.090	0.014	0.078	0.102	0.100	0.036	0.048	0.031	0.086	0.012	0.074	0.027	0.053	0.073	0.022	0.033	0.020	0.089	0.036
VR19	0.147	0.154	0.021	0.112	0.141	0.144	0.064	0.038	0.054	0.126	0.028	0.103	0.053	0.077	0.105	0.082	0.089	0.070	0.040	0.058
VR20	0.106	0.099	0.011	0.047	0.099	0.087	0.068	0.020	0.041	0.082	0.007	0.046	0.039	0.022	0.028	0.013	0.044	0.036	0.019	0.008

The present study employed the DEMATEL approach to ascertain and rank the most key drivers that contribute to supply chain complexity within the footwear sector. Twenty drivers were identified for this investigation, and the cause-and-effect drivers were identified along with their interrelationships using this approach. As shown in Table 7, the drivers in the study were categorized into two classes based on the analysis results of their classification. Drivers with negative SR-SC (effect) values are affected with positive SR+SC and SR-SC (cause) values of drivers. Based on this, the result in Table 7 indicated that market uncertainty and risk (VR19), process uncertainty (VR12), technological innovation (VR11), number of customers (VR14), changing need in customer demands (VR16), trends in the market (VR18), heterogeneous demand (VR20), number of processes (VR8), processes interactions (VR9), variety of customers (VR15), suppliers' reliability (VR4), geographic span of suppliers (VR3) were identified as cause drivers. As shown in Table 7, the driver with the highest rating for the cause group is Market uncertainty and risk with SR-SC value (1.04). The factors listed below are also in the cause driver group and have a significant impact on the on effect group drivers: process uncertainty (0.74), technological innovation (0.65), number of customers (0.59), changing need in customer demands (0.53), trends in the market (0.47), heterogeneous demand (0.42), number of processes (0.33), processes interactions (0.28), variety of customers (0.26), suppliers reliability (0.06), geographic span of suppliers (0.03).

Table 7
Significant and relationship results obtained by using the DEMATEL method

Drivers	SR	SC	SR + SC	SR - SC	Cause or effect
Number of suppliers	0.26	1.68	1.95	-1.42	Effect
Variety of suppliers	0.46	1.45	1.90	-0.99	Effect
Geographic span of suppliers	0.15	0.12	0.27	0.03	Cause
Suppliers' reliability	0.80	0.74	1.53	0.06	Cause
Variety of products	1.02	1.67	2.69	-0.65	Effect
Number of products	0.98	2.00	2.99	-1.02	Effect
Variety of manufacturing process	0.30	0.72	1.02	-0.41	Effect
Number of processes	0.88	0.54	1.42	0.33	Cause
Processes interactions	0.89	0.61	1.49	0.28	Cause
Forecasting inaccuracy	1.34	1.74	3.08	-0.40	Effect
Technological innovation	0.65	0.00	0.65	0.65	Cause
Process uncertainty	1.64	0.91	2.55	0.74	Cause
Employee induced variability	0.12	0.56	0.68	-0.44	Effect
Number of customers	1.34	0.74	2.08	0.59	Cause
Variety of customers	1.07	0.81	1.88	0.26	Cause
Changing need in customer demands	0.89	0.36	1.25	0.53	Cause
Demand variability	0.69	0.76	1.45	-0.07	Effect
Trends in the market	0.82	0.36	1.18	0.47	Cause
Market uncertainty and risk	1.53	0.48	2.01	1.04	Cause
Heterogeneous demand	0.54	0.12	0.66	0.42	Cause

Conversely, the result of this study identified eight effect drivers which are: number of suppliers (VR1), number of products (VR6), variety of suppliers (VR2), variety of products (VR5), employee induced variability (VR13), variety of manufacturing process (VR7), forecasting inaccuracy (VR10), demand variability (VR17). These eight drivers found in the effect group are heavily impacted by the drivers in the cause group. Therefore, concurrently improving or controlling the cause group drivers also improves the effect group drivers. This suggested that group drivers require greater focus in order to control the complexity of the supply chain caused by group drivers. Accordingly, the top five cause group drivers that require the greatest attention are: market uncertainty and risk, process uncertainty, technological innovation, number of customers and changing need in customer demands.

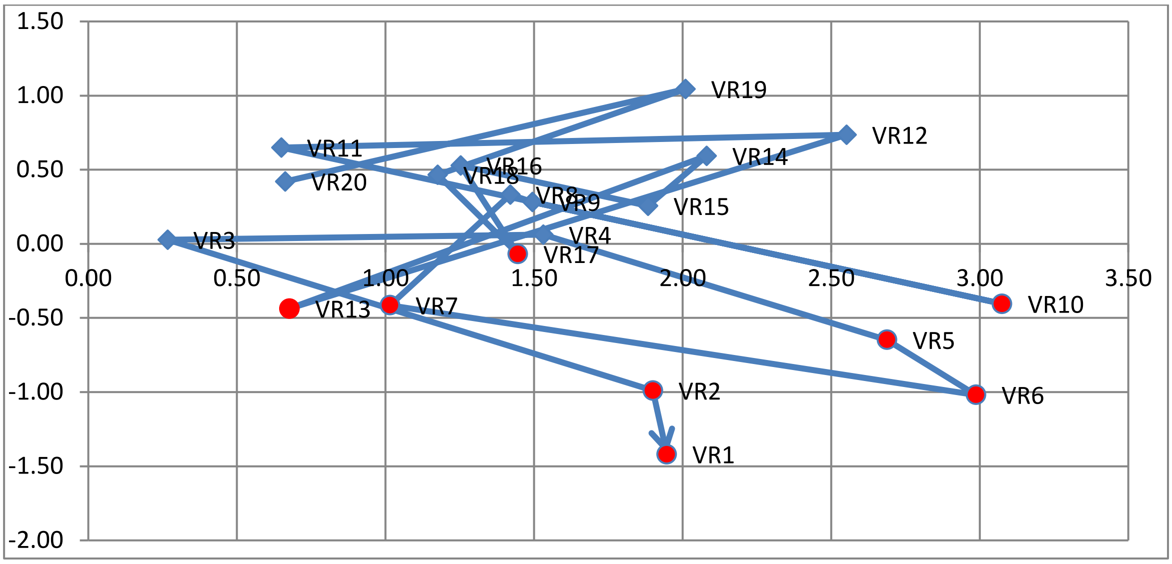

Fig. 3. DEMATEL causal and effect diagram

According to the results in Fig. 4 there are four drivers in the linkage category that have strong driving power and dependency: market uncertainty and risk (VR19), number of customers (VR14), process (manufacturing) uncertainty (VR12), and variety of customers (VR15). Any modifications made to these group drivers will have an impact on other drivers as also feedback on themselves. Because of their dynamic nature, these drivers may cause the supply chain network's complexity to increase or decrease. The dependency and driving power diagram in Fig. 4 indicates the independent drivers such as Technological innovation (VR11), Heterogeneous demand (VR20), Geographic span of suppliers (VR3), Trends in the market (VR18), Changing need in customer demands (VR16), Number of processes (VR8), Processes interactions (VR9), and Suppliers reliability (VR4). These group drivers have significant driving power effects but low dependence. Thus supply chain complexity managers need to address their drivers more carefully and treat them as vital drivers that increase complexity in the network.

Dependency and driving power diagram in Fig. 4 indicates that there are three autonomous complexity drivers Employee induced variability (VR13), Variety of manufacturing process (VR7), Demand variability (VR17). Due to their limited impact on the complexity of the supply chain, these autonomous drivers have been removed from the system. The results shown in Figure 4 indicate that while forecasting inaccuracy (VR10) and variety of goods (VR5), number of suppliers (VR1), variety of suppliers (VR2), and number of products (VR6) are insignificant complexity drivers, they are substantially influenced by others. Of these, the top three drivers most greatly impacted by cause group drivers are number of suppliers (-1.42), number of products (-1.02) and variety of suppliers (-0.99) (Table 7). This revealed that in order to reduce their influence on these drivers, the top cause group drivers should be effectively controlled.

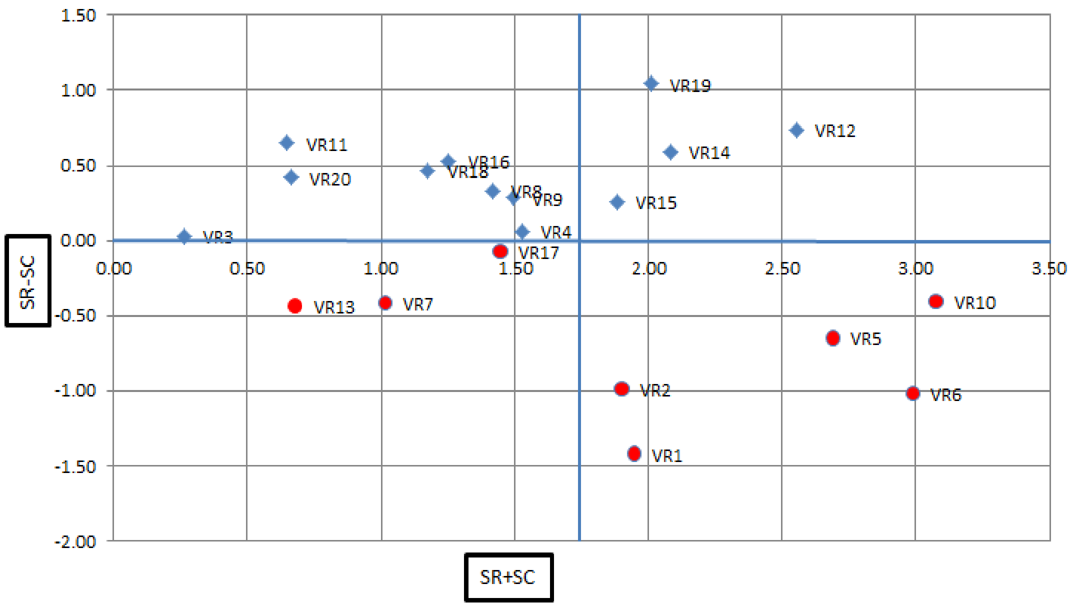

Fig. 4. Dependency and driving power diagram

5. Conclusion

The present study employed the DEMATEL approach to ascertain and rank the most key drivers that contribute to supply chain complexity within the footwear sector. Twenty drivers were identified for this investigation, and the cause and effect drivers were identified along with their interrelationships using this approach. To identify the significance effects of drivers on complexity SR+SC values are used. And to group or classify the drivers based on cause and effect, SR-SC values were considered. The DEMATEL Causal and effect helps to convert complex relationships and understand in an easy way the drivers that create complexity in the footwear supply chain. Based on the findings of this study, decision makers in the business sector should be focused on market uncertainty and risk, number of customers, process (manufacturing) uncertainty and variety of customers (VR15) to improve the performance and to control the effect of drivers.

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