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ORIGINAL ARTICLE

Examining the impact of managers' network size on SME performance: a case study of Interurban and local road freight transport in the Paris department

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Abstract
This study focuses on the interplay between managers' personalities, relationships, and company performance. We investigate the influence of managers on a sample of small and medium-sized enterprises (SMEs), specifically examining the size of their networks. Our focus is on enterprises working in the sector of interurban road freight transport and local road freight transport within the Paris department. The model we propose aims to understand the advantages of a well-established and interconnected network for SME performance. We analyse how the different characteristics of a company as well as its manager's personality and network ties can affect company performance. By drawing upon the dependency network approach, the Resource Dependency Theory, and network theory, we investigate the connection between resource and network dependencies, and how these influence firms' behavior and long-term growth. Through our theoretical review and by analyzing a database of selected companies through the multiple linear regression and the Principal Component Analysis, we find that networking plays a vital role and significantly impacts a company's revenues and costs, although not to the extent that we predicted. The results of our research provide evidence of the correlation between networking and performance ratios, but only partially confirm our hypotheses.

Keywords Managers · Networking · Dependency network approach · Performance · Revenues

1 Introduction

In order to achieve sustainable long-term growth, enterprises must rely on a diversity of services and resources, of which networks are a crucial part. In today's data-driven world, understanding how networks function is of crucial importance. As one of the leading authorities on the subject, Burt [1] examined corporate networks and explained their considerable influence on the decision-making process within companies. We will thus start from his understanding of corporate networks to discuss how managers of small and medium-sized enterprises (SMEs) can use their personal and professional networks to improve company performance and foster the above-mentioned long-term growth. To this end, research carried out by Gharsalli [2], by Jackowicz and Kozłowski [3] as well as by Soetanto et al. [4] will be a starting point for our research, since they highlighted how networks can contribute to companies' growth, resilience, and sustainability. Overall, our research is grounded in several key theories, including the dependency network approach, network theory, and the Resource Dependency Theory. We aim to draw connections between each of them to highlight how asymmetries in resource control can even lead to dependencies regarding networks. Through our work, we hope to contribute to the literature on corporate and managerial networks, and to find a positive relationship between such networks and the performance of SMEs, so that we will be able to confirm the initial hypothesis that corporate networks are vital for a business' success and

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can improve firms' robustness. In addition to this, we hope to bring our contribution to the field by offering a specific insight into the influence of networks on the freight transportation sector. We consider this to be especially relevant today, since optimizing transportation networks has become a critical aspect of business operations.

Discussing networks entails addressing them in their original conception. In this sense, a social network can be defined as a group of people connected by a type of relationship, whether it is a friendship, partnership, or even a casual relationship, which is what Granovetter [5] calls a "weak tie". Our study seeks to comprehend and dissect the constituent components of managerial networks, as well as their influence on a company's revenue. To accomplish this, we will employ the dependency network approach, which will enable us to elucidate the dynamics of power and interdependencies among the nodes within the networks under examination. Besides carrying out a review of the literature on the primary subjects of our study (from key theories on networks to the personality of the manager and company performance), we will further conduct a statistical analysis on a variety of factors related to the personal and professional network of a sample of 71 managers of freight transportation companies of similar size, sector, and geographical area. Then, our analysis will assess the quality and quantity of managerial connections before incorporating various characteristics of the chosen companies, such as their age, size, and turnover. This comprehensive approach will allow us to determine which of these factors exert the greatest influence on company performance. To these ends, we will primarily use tools such as the multiple linear regression and the Principal Component Analysis. These advanced statistical analysis techniques will allow us to extract meaningful insights from complex datasets, demonstrating the practical applications of data science in real-world scenarios. As depicted in Fig. 1, our research unfolds in four stages: beginning with an introduction to the context and a literature review to determine the major theories on the subject, we then proceed with a statistical analysis of the data gathered on the performance of enterprises (considering factors such as seniority and size) and their managers (age, number of mandates, indirect and direct links, etc.); finally, we conclude with a discussion of our findings.

2 Academic literature review

To explain the relationship between a manager's network and the success of his company, many definitions have been given. Thus, we will start by defining the terminology that is pertinent to our research, such as SMEs, company performance, and networks. We will discuss the manager, his role, and the centrality of his personality for the success of his business. Finally, we will focus on the common characteristic of the companies in our sample: the freight transportation sector in the Paris department, to highlight its critical aspects for our study.

2.1 SMEs

SMEs, or small and medium-sized enterprises, are "companies that employ less than 250 people, and that have a turnover of less than 50 million euros annually, or a balance sheet total not exceeding 43 million euros" (INSEE,

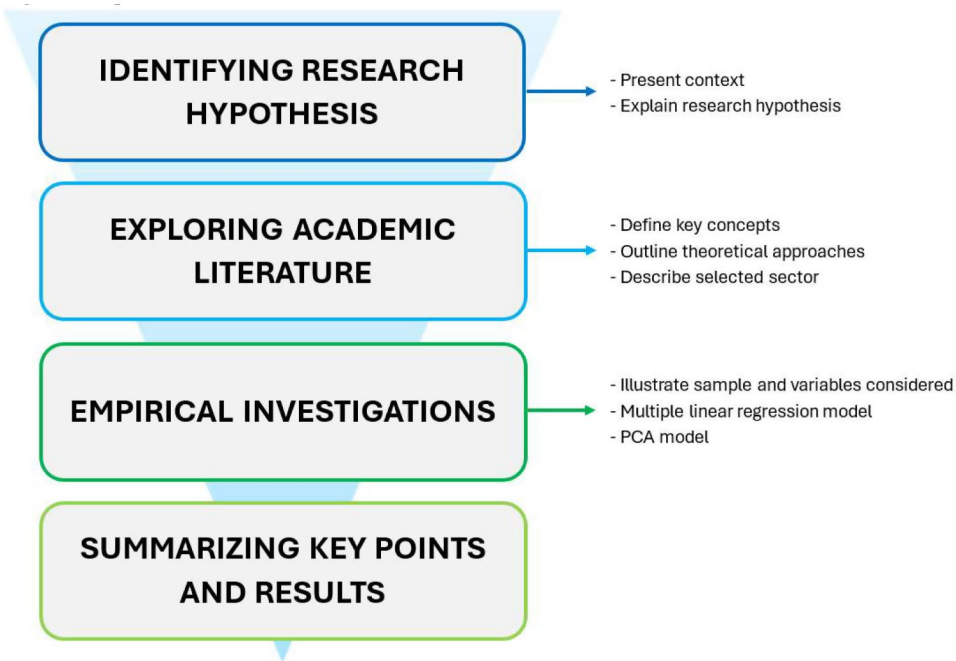


Fig. 1 Conceptual framework

2019). Influenced by their size, management techniques will vary from one SME to another. For instance, the smaller the company, the more its performance will depend on the strategy of its management. According to a study by Kalika [6], a manager's authority tends to be more concentrated in small and medium-sized companies, whereas it is more often decentralized in larger companies. This distinction in the administration mode based on dimension is essential. Data-driven approaches will allow us to analyze how managerial strategies impact performance, shedding light on the evolving landscape of business management.

Managers play a key role for the success of SMEs, but a company's performance is also influenced by its board of directors. Indeed, a misalignment between the interests of managers and shareholders could arise, and it is possible that a manager would rather pursue his own interests over those of the business. Therefore, the board of directors is crucial in safeguarding the interests of the owners. It closely tracks the conduct and choices of the management team to ensure the company's operational efficiency and prevent expenses that would compromise its financial condition. As mentioned above, managers play a crucial role in SMEs, where their decision-making powers tend to be concentrated. A significant difference that occurs between smaller and larger enterprises pertains to their mode of financing. Indeed, Gharsalli [2] notes in his research that managers of large businesses often enjoy privileged ties with financial institutions, which enable them to receive the advantage of lower loan rates. Additionally, managers of large companies will typically have greater exposure to potential investors compared to managers of small companies, mainly due to the extent and nature of their network. The network of SME managers (most of whom have little engagement with financial institutions) can help further clarify why SMEs, especially French businesses, favor debt financing over equity, which is the opposite of large enterprises. Consequently, though the manager's job is crucial, the company's size restricts its range of operations.

2.2 Performance measurement

Performance is a complex topic to define because it varies based on its measurement and study. Indeed, turnover, ROA (Return on Assets), ROE (Return on Equity), and many other financial ratios can be used to assess a company's performance. However, research done by Kaplan and Norton [7] shows that measuring performance solely through financial elements is not sufficient, due to the intricate nature of the environment in which businesses currently operate. For this reason, they devised the Balanced Scorecard (BSC), now one of the most useful tools to measure performance in a multidimensional manner. Evidence supports the effectiveness of the BSC as a means for companies to achieve sustainable development in all areas [8] (See Fig. 2).

This is one of the main approaches used to assess business sustainability performance, as it incorporates environmental, social, and ethical concerns [9]. The image below illustrates the various aspects of performance analysis examined through the prism of corporate strategy. These include the financial perspective, the internal perspective, the customer perspective, and the organizational learning [10] (See Fig. 2).

Anggadwita and Mustafid [11] provide another theoretical framework for evaluating the performance of SMEs that takes into account four key criteria, as shown in Fig. 3: innovativeness, sustainability, human resource competency, and entrepreneurial aspects. As human behavior stands as a pivotal determinant in the functioning of a business and given its potential for change or consistency over time, the entrepreneurial dimension assumes paramount significance.

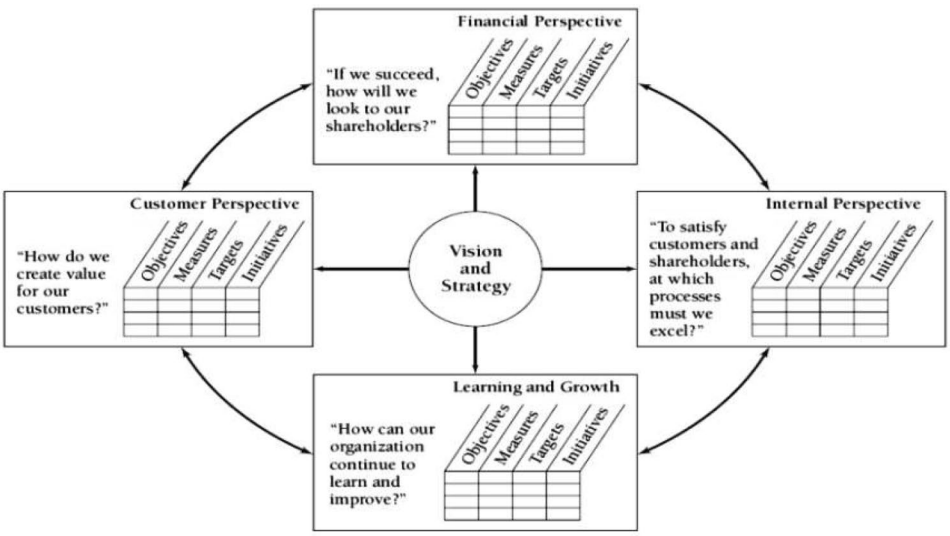


Fig. 2 The balanced scorecard (BSC): four perspectives

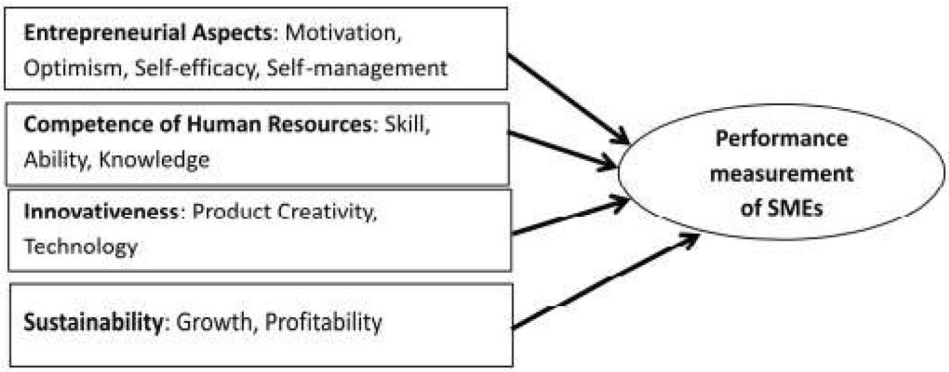


Fig. 3 Theoretical framework for measuring performance of SMEs

Specifically, one's personality exerts a significant impact on the performance of Small and Medium-sized Enterprises (SMEs), with attributes such as motivation, optimism, self-efficacy, and self-management potentially dictating an entrepreneur's success in managing a business. We will later delve with greater depth into the personality of the manager to assess how it influences performance. Secondly, performance relies on the comprehension of the knowledge and the skills required to perform well. Thus, *competence of human resources* is essential for businesses to cope with new obstacles when faced with growing market competition. Thirdly, *innovation* plays a crucial role in maintaining and improving organizational effectiveness. We are primarily considering technological advancements and product innovation. Ali et al. [12] have emphasized this concept as key for maintaining competitiveness and ensuring a company's success. Finally, given that it is proof of a SME's potential to survive and expand, *sustainability* is also vital in assessing company performance. The development and profitability of the business are considered as sustainability factors.

Many studies before ours have chosen to focus on corporate networks as a key tool to measure performance. As Yeniaras and Unver [13] have demonstrated, professional ties, whether strong or weak, are linked to innovation. They found that a combination of exploratory and exploitative practices is necessary for businesses to achieve success in the long run. Additionally, Soetanto et al. [4] has found that networks improve company performance, as they are a valuable resource used to overcome internal and external obstacles; this is particularly true when they are updated to current business needs. A fixed and unchanging network will not provide managers with up-to-date resources and knowledge necessary to overcome adversity. Moreover, having new and adaptable social ties allows managers to gain access to the extensive information needed at the very moment when the company faces challenges. Thus, diverse and well-integrated networks are vital when dealing with obstacles. When it comes to utilizing resources for purposes such as market research, fundraising, or recruiting experts to tackle challenges, networks can be likened to a dependable safety net for companies. These networks are commonly linked to key business outcomes like growth, innovation, and sustainability. Therefore, drawing upon existing research in the field, our study endeavors to determine whether, within our sample of companies, corporate and managerial networks alone can sufficiently account for company performance.

2.3 Network definition and the case study of Paris' networks

Social networks are essential for business growth. They offer several material and immaterial assets that promote development and innovation, since they create links between individuals and enable the emergence of the necessary trust in relationships [14]. Our study utilizes the dependency network approach to analyse network dynamics; we must then define networks and how they are understood according to this model. Networks are comprised of nodes which are connected to each other through links. In our case, the nodes are represented by individuals: the manager under scrutiny and the persons belonging to his social circle. The links that connect them are, comprehensively, the relationships that exist between them. Networks may vary in terms of their structure (internal or external, alumni, customers, or suppliers), size (the number of people connected to the manager), and the type of links (strong or weak) that bind the network's actors together. The dependency network approach aims at analyzing network activity and, in particular, at finding potential correlations and influences between each of the nodes [15]. Consequently, we aim to understand the relationships between the network actors, i.e., the nodes, whether and how they influence each other, and which power dynamics are at play. Overall, network dependencies are at stake in our research since we are investigating how managers' ties influence performance. Thus, we expect that a manager's network can possess those resources that are normally lacking for the company but could improve its performance. Given a potential asymmetry in resource control

between the network nodes, power imbalances are also at play. Emerson holds that the less an individual depends on another, the more powerful he is [16]. Hence, dependencies emerge as a result of the previously mentioned disparity in resource ownership among network participants. For instance, if one node possesses the resources essential for another node's business viability, a dependency situation is created [17]. Consequently, our study seeks to examine these dependency relationships among the nodes and illuminate the associated correlations.

After defining networks, we must focus on their effects on SMEs. In support of our hypothesis that managers' networks have an impact on businesses' performance, Jackowicz and Kozłowski [3] observe that social ties improve SMEs' ability to obtain bank funding and increase investments, even though this beneficial effect only happens when bank executives are involved. Furthermore, previous research has indicated that SMEs' access to credit is facilitated by trust in the relationship between borrower and lender when banks lack formal information (such as business plans, financial statement data, and credit ratings) to make a sound financing choice [18]. In his research on the effect of networking on SME finance, Gharsalli [2] concluded as well that a manager's personal and professional connections can improve borrowing rates for his company, even at discount rates. Strong links can result in considerable resource flows, both directly to leaders or indirectly to their organizations, but they are considerably more challenging to establish and maintain over time compared to weak links [5].

As far as the city of Paris is concerned, a study carried out by Andreotti et al. [19] found that the vast majority of the managers interviewed said they regularly used neighborhood amenities like public transportation and schools, and they focused on their involvement in city life and social events in the community. The neighborhood's social structure is reflected in this pattern as being comparatively homogeneous. These respondents used public services more frequently in locations with a higher proportion of upper-middle-class citizens than in places with more diverse populations, where they tended to rely more on the private sector, particularly private schools. Less than one in ten of the managers in Paris participated in neighborhood activities or community organizations. These results demonstrate that they are not actively involved in civic or political affairs in their communities; they also suggest that they do not support "participation strategies", at least not in conventional local public spaces. In comparison to Milan or Madrid, for example, the responders from Paris had more open and varied social networks.

2.4 The manager

In the age of digitalization, we also need to consider managers' personalities and conduct in digital environments, as well as the difficult digitization process in SME networks [20]. The strong interconnectivity of the Internet might be an asset for business owners, who ought to be conscious of their influence over users' behavior. To identify the numerous roles and personalities adopted by entrepreneurs in digital settings, González-Padilla et al. [21] have differentiated between digital entrepreneurs' personalities and they have studied how each of these interacts with their surroundings and with digital businesses.

Some leaders will be inclined to utilize their networks to gather relevant information, while others will not. Therefore, much of how networks can be leveraged depends on personality: this is why managers' personality should be investigated in order to examine its possible connection with network usage. An individual's personality can be described using a variety of theoretical approaches. Digman's "Big Five" model [22] is one of them. According to this model, a leader's personality is evaluated based on five key traits: friendliness, introversion or extroversion, rigor, emotional stability, and intellectual curiosity. Studies found that what contributes most to businesses' success in the long term is managers' diligence and conscientiousness [23]. Whether a manager possesses a resource-dense network and whether he can effectively leverage his network may not only benefit the company for all the above-mentioned reasons, but it may also benefit the manager himself. Indeed, a well-connected manager with an ample social circle can potentially capitalize on his asset to gain higher compensation, authority, and prestige within the company as well as within other companies. Word of mouth and recommendations can effectively even secure managers an executive position in other firms. As per Collins and Clark's [23] findings, acknowledging and appropriately rewarding the positive spillover effects of a well-leveraged network generates a positive feedback loop that incentivizes managers to expand their connections and fosters a culture of information sharing.

In their article "Interfirm Alliances in the Small Business", Barnir and Smith [24][12] have examined four factors that can help us understand how managers behave, that are:

[1] Professor Anat Barnir of the University of Texas specialises in decision-making, entrepreneurship, and competitive behaviour and positioning in her current study. These research trends involve the implications of management traits, corporate structure, and networks of interpersonal relationships between rival firms.[2] President Ken Smith oversees directing and increasing support for the company as a whole in his capacity as Geneva College's CEO and top spokesperson. It acts as a formal link between the teachers, students, and staff and the Board of Governors. It has broad oversight and control over the entire college.

their propensity to engage in networks, the extent of their network activity, the degree to which they interact with other, and their managerial status. Managers' propensity to establish and maintain a sizable network of contacts is referred to as the *network leader's propensity*. This openness is characteristic of extroverted individuals who believe they are developing relationships with others. To build a relationship, the best course of action is often to volunteer in social organizations like sports teams or professional organizations. Furthermore, the manager must make optimal use of his network to increase both the quantity and quality of information his company receives, as it is crucial for corporate growth and the development of resources. Other authors have focused on the characteristic of extroversion, which they consider to be particularly relevant for individuals holding managerial positions. In the context of our research, this finding is important because extroverts are found to invest more time and effort in building relationships and cultivating them, as well as to be more willing to trust people around them. Thus, it appears that extroverted individuals holding a management role are in a privileged position regarding to network-building [25, 26].

2.5 RDT, network theory and structural holes

Our research is grounded on two fundamental theoretical approaches: the Resource Dependency Theory (RDT) and the network theory. Pfeffer and Salancik's Resource Dependency Theory [27] focuses on how external resources influence the functioning of organizations. Network theory, instead, comprises numerous theories, among which we find Granovetter's study on the strength of weak ties [5] and Burt's research on structural holes [1], which will be later explained. Borgatti and Halgin [28] have attempted to define network theory as a theory that "refers to the mechanisms and processes that interact with network structures to yield certain outcomes for individuals and groups". The authors highlight the importance of the structural position of the actors in a network, as it can, among other things, facilitate information flows. Borgatti and Halgin's findings on network theory are key for our study, as they explain how network theorizing focuses on "choice" and "success". The authors use the term "choice" to encompass the various beliefs, perspectives, and behaviors exhibited by the nodes in the network. When referring to "success", they are alluding to the effectiveness and actual performance achieved. Our research, indeed, places a central focus on understanding how personality, behavior, relationships, and performance are interconnected.

One key focus of the RDT is the "ecology of the organization", that is the environment in which organizations exist. Indeed, one of Pfeffer and Salancik's core arguments is that the external environment should be taken into account to best understand organizations' modality of operation. The RDT holds that the way in which an organization acquires resources, whether internal or external, corporate, managerial, or inter-organizational, highly influences its behavior and overall survival: the more an organization can capitalize on its external resources, the more it will gain in competitiveness. Thus, we find again that resource control creates power asymmetries [16, 17]. We have chosen to focus on networks as central resources for the growth and sustainability of companies. Indeed, the RDT is often linked to the concept of organizational networks, as organizations usually lack all the resources they need, and thus can leverage their network connections to gain access to and control critical resources as well as diversify them [29]. Before us, other authors such as Gulati [30] have drawn connections between network theory and the Resource Dependency Theory, by demonstrating that networks represent for companies essential channels for information and can foster further inter-organizational alliances.

Most researchers on the subject agree that not all managers have the same personal or professional networks, and that not each of those networks have the same value. The structural hole theory, developed by Burt [1], is crucial for our analysis. We can define structural holes as voids between non-redundant contacts. The more connections a network has to other social circles, the greater the number of structural holes it has; and the wider the distribution of information is, the more people it impacts. This way, we can associate this concept to entrepreneurial success, as entrepreneurs with numerous structural holes in their networks are more likely to benefit from a varied knowledge base [31]. This idea was also illustrated by Zhu et al. [32] in the following graph that focuses on the network's entrepreneurs (See Fig. 4).

Burt also defines that the benefits that an individual may enjoy should he be in a position of privilege in comparison to other subjects. He does so in his article "Structural Holes and Good Ideas" [33]. The existence of a third subject, who serves as the "key" to the structure and is referred to as a "bridge" or "broker" (as seen in Fig. 5 [34]), is a requirement for Burt's model to function. As the model comprises three subjects, without this third "bridge" subject, subjects A and B are unable to communicate with one another.

Through his numerous works, Burt demonstrated that the concept of "bridge" offers two distinct services: the benefits of information (which could refer to the access and synchronisation of information) and the benefits of command (which allow the "bridge" subject to voice his views regarding the interests that have been created by the ties). The individual in a position of privilege is empowered to collect, filter, store, and convey desired information, thereby

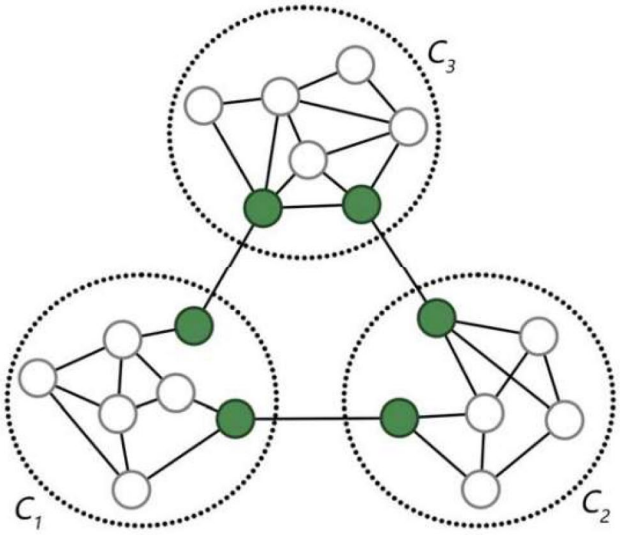


Fig. 4 Structural holes

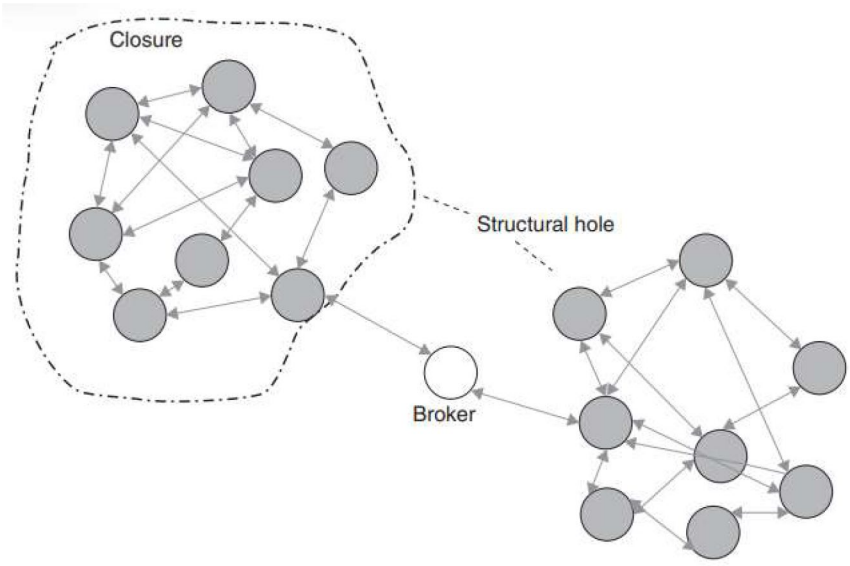
exercising substantial influence over the communication of other individuals. As mentioned above, accessing financial resources is facilitated by having a diversified social network [2, 3]. Similar to how network size and reporting frequency can affect capital growth and firm size, these executive resources can be of great advantage to the organization [24]. In their article "Personal Networks and Firm Competitive Strategy"[2], Ostgaard and Birley [35] presented such results. As a first step, to preserve existing ties and look for new relationships, devoting enough time to networking is necessary. In addition, the standing (and thus prestige) of a manager is crucial, as people are more inclined to establish and maintain ties with people with a high social status. Consequently, relationships with third parties are extremely important.

2.6 Interurban and urban road freight transport

Our investigation centres on SMEs in the interurban road freight transport and local road freight transport sector within the Paris department. From the standpoint of microeconomics, road freight transport converts inputs, such as vehicles, energy, and manpower, into outputs, so transport activities [36]. In this respect, the Paris metropolitan area is extremely well-connected owing to several motorways that link the agglomeration's core to its outskirts, and terminals and goods communities are found typically along the route corridors. This region, called Ile-de-France, represents one of the largest concentrations of economic activity in Europe, and it accounts for a third of the French GDP. Due to the unavoidable transfer of commodities, entering the agglomeration is seen as a disruption in the supply chain's seamless flow, and consequently it is considered advantageous [37]. Regarding freight volumes, the Paris region exhibits a relatively small disproportion between inflows and outflows. In particular, 31% of the tonnage of freight transported to the Paris region is finished goods, and 9% is food items; 55% of the quantity of carried goods is internal, 25% is inflow, and 20% is outflow. The majority of the tonnage of goods moved inside, to, or from the Paris region is carried on roadways, accounting for 88.6% of the territory's total tonnage [38]. While 30% of travel lengths are made outside of the metropolitan region, 11% of traffic in Paris is concentrated there. Around 8% of all trip miles are made up of urban road freight. However, this share varies significantly

[2] Professor of entrepreneurship at Imperial College Sue Birley will guide the college's efforts to establish itself as a premier hub for promoting scientific research commercialisation and business education in both undergraduate and graduate programmes.

Fig. 5 Structural holes, brokerage, and closure



throughout space. In Paris, LGVs (Large Goods Vehicles) and HGVs (Heavy Goods Vehicles) account for 16% of the miles driven compared to interurban areas 2.6% [39]. Additionally, the agglomeration presents significant challenges for pooled flows of heavy vehicles due to the congested streets and other drivers' rivalry. Alongside this, we can also add the challenge of parking goods vehicles while they are making deliveries in crowded urban locations. For this reason, transport companies prefer to switch over their cargo from huge trucks to lighter vehicles, which are better suited to driving and parking in crowded metropolitan areas. In fact, over 60% of weekly shipments and pick-ups in Ile-de-France are handled by light vehicles (3.5 tonnes or less) [37]. Urban supply follows a hierarchical structure, leading to most interurban flows taking place between urban regions of differing densities. The characteristics of the supply chain undergo significant alterations based on the hierarchical level of the urban area. In this case, smaller urban areas primarily supply Paris and the larger cities, and these supplies are lighter than usual. Small urban and rural locations, on the other hand, receive heavier-than-average imports from higher levels of urban hierarchy [40].

3 Research hypotheses and empirical investigations

This section articulates empirical evidence, underscored to accentuate the significance and implications of our research hypotheses. Building upon the comprehensive exploration of scientific literature delineated in the preceding sections, we now transition to a focused examination of the methodologies employed in our study. This juncture represents the confluence of theoretical insights and empirical inquiry.

To advance in this study, we formulated two research hypotheses, H1 and H2, to investigate the impact of networks on enterprises within the freight transportation sector in the Paris department. The first, H1, aims at investigating the impact that networks have on the robustness of a SME, while the second, H2, aims to explore the significance of networks within the considered sector.

These hypotheses are thus defined as:

- *H1: Broad and diverse SME managers' networks foster firm robustness.*
- *H2: Networks highly influence the performance of freight transportation SMEs in the Paris department.*

In the development of H1 and H2, we invoke a corpus of established scholarship to dissect the ramifications of networks on business entities operating in the Parisian freight transport sector. It is imperative to anchor the research hypotheses in a robust theoretical edifice as delineated in the preceding discourse.

H1 is predicated on the premise that expansive and multifaceted managerial networks are pivotal to SME fortitude. Pioneering work by scholars such as Granovetter [5] and Burt [1] underscore the vitality of cohesive networks, replete with diverse stakeholders and resources, in bolstering the resilience and flexibility of SMEs. Moreover, research conducted by Gronum et al. [41] emphasized the importance of well-established networks, comprising various stakeholders and resources, for the resilience and adaptability of small and medium-sized enterprises. Thus, we posit that network breadth and heterogeneity correlate positively with enterprise steadfastness. Besides, Cisi et al. [42] have further investigated the effects of networks on firms' economic performance, finding that this effect is stronger for small SMEs in their analysis of a representative sample of Italian SMEs. Overall, they claimed that formal networking is a useful tool for improving the performance of businesses. Finally, worth citing is the article by Hoang and Antoncic [43], which highlights how the analysis of the impact of networking on firms' performances is one of the main emerging fields of investigation within network research.

Addressing H2, we posit that networks play a crucial role in shaping the efficacy of freight transportation SMEs in Paris. This stance is corroborated by empirical findings from Marchese et al. [44] who indicate, in relation to the Andalusian example, the significance of collaborative networks in optimizing operational efficiency.

By exploring the impact of networks within our specific context, we aim to contribute to the growing body of knowledge regarding the interconnectedness of business networks and sector performance.

This research investigates the connection between the business' performance and its manager's network characteristics. We selected 71 businesses from the transportation industry, specifically focusing on businesses working on interurban and urban freight transportation within the Paris department. [3] We chose to provide insight into this domain, as we consider that optimizing transportation networks is a critical aspect of business operations. The companies analyzed were chosen depending on their performance traits (which include indicators and company ratios), their features (size, seniority), and, lastly, their manager. The main methods for multidimensional data processing were used to conduct our analysis. When examining the connections and correlations between a dependent variable and two or more independent variables, the multiple linear regression line is a valuable tool, as is the Principal Component Analysis (PCA). The primary goal of the PCA is to evaluate the data

[3] Our initial research identified more than 80 companies, but after eliminating entries with missing data, this is our final count.

while taking into consideration their multidimensionality, allowing for a close examination without sacrificing crucial information.

Network dependencies are at stake in our research since we are investigating how managers' ties influence performance. Thus, we expect that a manager's network can possess those resources that are normally lacking for the company but could improve its performance.

In Sect. 2, we delved into how the network dependency approach, Resource Dependency Theory, and network theory have scaffolded our study within a framework of resource interdependence. In this paper, we are investigating how managers' ties influence performance; thus, we expect that the resources that managers can obtain through their networks are those that companies normally lack but that can improve performance if accessed and correctly leveraged. Authors before us already studied network dependencies and the links between company performance and social ties. Prior research by luminaries such as Soetanto et al. [4] showed that diversification in managers' networks is a key tool that companies can utilize when facing internal or external obstacles. Networks, and in particular network change, they hold, can facilitate overcoming hardship. Yeniaras and Unver [13] proved that social connections are tied to greater innovation within companies. Moreover, Gharsalli, Jackowicz and Kozłowski [2, 3] demonstrated that, through their networks, managers of SMEs can have access to funding resources and financial support that they could otherwise struggle to obtain. Networks provide access to crucial resources such as knowledge and ties with the external environment, which can enable companies to obtain privileged information about trends, market demands, customer preferences, and potential investors' expectations. Additionally, the wider and more diverse the network is, the better companies can mitigate risks and adapt to disruptions, thanks to the collaboration and resource sharing between the various network nodes. Therefore, because networks facilitate access to funding, an inevitably crucial aspect of business operation, and because they allow firms to better address difficult circumstances, we can connect this aspect to research hypothesis **H1**. We have chosen to focus on firm robustness as we believe that networks can significantly and particularly foster resilience within companies. Additionally, as we have decided to investigate the impact of networks more specifically on our sample of enterprises, we have formulated a second hypothesis **H2** that focuses on the overall performance of the selected companies working in the freight transportation sector in the Paris department. We expect to find significant positive correlations between the network nodes, and thus to confirm both our following hypotheses through our statistical analysis of the data gathered on our sample of enterprises.

Prior to our statistical exploration, a subsequent section will meticulously catalogue all variables under consideration. In quantifying managerial network links, we adhere to Burt's concept of structural holes, accounting solely for non-redundant ties, thereby excising superfluous connections and enabling a discussion on bridges to disparate social clusters.

3.1 Explanation of variables

Both 'Societe.com' and 'Dirigeant.com' websites provided the data from which all variables were gathered or calculated. In terms of the available legal and financial information for French businesses, 'Societe.com' has been the market leader for fifteen years. With approximately ten million companies updating the information concerning their business every day, this website offers the most complete database available online. Figure 6 shows an example of the synthetic financial analysis provided by the site, which includes the company's rating, its balance sheet, and its level of profitability. Its equivalent for information on all French managers and leaders (who amount to five million executives), their mandates, and networks of influence is the Dirigeant.com website. Each leadership team is mapped out in the site, as shown in Fig. 7.

- *Selected sample*: consisting of 71 businesses that operate in the same industry (*Local and interurban road freight transport*), share the same region (the department of *Paris*), and employ between 5 and 50 people. After 2010, the data were updated.

Fig. 6 Synthetic financial analysis of the Societe.com site

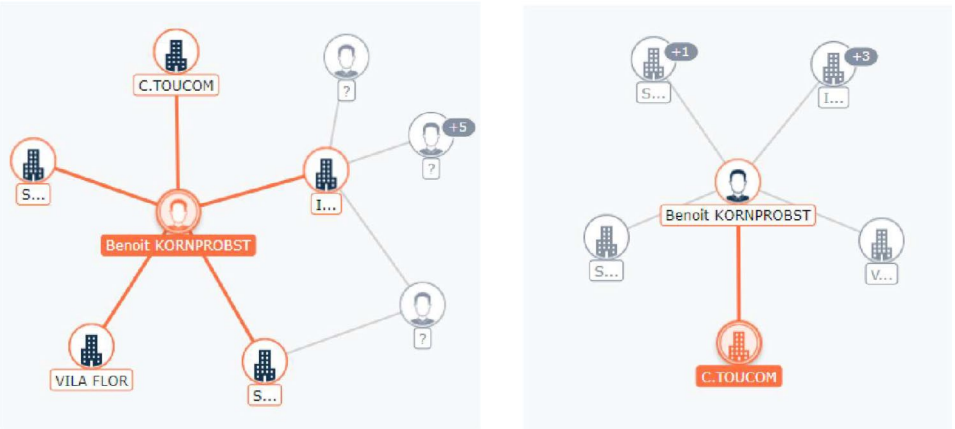


Fig. 7 Enterprise mapping of the Dirigeant.com site

Table 1 Adjustment quality factors

Statistic	Value
Residual standard error	0.185 on 64 DF
Multiple R-squared	0.818
Adjusted R-squared	0.807
F-statistic	72.1 on 4 and 64 DF
p-value	< 2.2e-16

- *Sector*: the industry in which the company operates is the same for all the other businesses in the sample. We have selected the two sectors of *Interurban* and *Local Road freight transport* for this study.
- *SIREN number*: "Each company is identified by a unique identification number: the SIREN number. It is used by all public bodies and all administrations related to the company. Assigned by INSEE when the company is registered in the Sirène directory, it has 9 digits. This number is unique and invariable. It breaks down into three groups of three digits assigned in a non-significant way based on the order in which the company is registered".[4]
- *Number of employees*: this is the company's employee count, which ranges between 5 and 50 for all businesses.
- *Seniority of the company*: this indicates how long the company has been in business since its founding. The capital companies' corporate forms are indicated by *SA(S)* and *SARL*.
- *Revenue*: it is the total amount of goods or services sold and which are invoiced during a fiscal year. Revenue is provided duty-free. A company's turnover is a reliable indicator of its activity and size.
- *Fixed assets*: it refers to the asset that the business intends to keep permanently. It relates to anything that is required for exploitation but is not destroyed by it, as opposed to present assets.
- *Current assets*: they cover inventories, trade receivables, and deferred charges. Contrary to fixed assets, which can be monetized in a year, they indicate operating resources, or all resources employed daily.
- *Inventory*: these are goods that a company buys, processes, or has available for sale but has not utilised or sold yet. To satisfy future needs, there must be enough stock on hand, yet having too much would cost a lot to store.
- *Availability*: the cash account and the available balances on bank accounts are considered a company's liquid assets.
- *Equity*: this includes the share capital, the reserves, and the financial year's profit or loss. Shareholders can raise it by setting away profits, which would prevent dividends from being distributed from them.
- *Total* debts: this is the amount on the balance sheet that was made accessible by a company's creditors. *VA* stands for *value added*, and according to INSEE, it is "the balance of the production account, equal to the value of production minus intermediate consumption." It is helpful for determining the worth of the production that a business produces.[5]
- *EBITDA or gross operating surplus*: it is an indicator of financial performance that, without taking investments or financial management into account, identifies the resource that a firm regularly obtains from its current activities.
- *Net income*: it displays the difference in a company's income and expenses over a specific period of accounting.
- *Company Rating, Balance Sheet and Profitability*: each company is given a financial analysis on the Societe.com website. This service enables a financial assessment using artificial indicators that are calculated theoretically using financial ratios.

[4] https://www.apce.com: The French National Agency for Business Creation aims to coordinate national and local action in favour of entrepreneurship.

[5] INSEE (the National Institute of Statistics and Economic Studies) analyses and publishes official statistics in France.

- *Number of total links*: these are the total connections between individuals.
- *Capitalization*: this indicates the ratio of the company's capital to the total on the balance sheet as a percentage.
- *Indebtedness*: this shows as a percentage the amount of debt determined by the fixed capital owned by the company.
- *Self-financing capacity*: this indicates as a percentage the number of internal resources produced by the business as a result of the operations that secure its funding.
- *Value added rate*: this assesses the effectiveness of the production tool, the company's contribution to the value of production, in percentage terms.
- *Operating profitability*: this represents the profitability of a business' current operations as a percentage.
- *Final net profitability*: this displays the profitability of the business in relation to its level of activity as a percentage.
- *Labour costs*: these reflect the cost burden of all business expenses associated with the usage of manpower as a percentage.
- *Immediate liquidity (in* days): this indicates the ability of the company to satisfy short-term obligations with resources that become liquid within the same time frame.
- *Supplier delay* (in days): this reflects the suppliers' regular payment schedule.
- *Leader's name*: there may be a single leader or three.
- *Number of mandates*: this represents the total number of terms the officers have held office. If there are more leaders, the stated figure will be the average of their number of mandates.
- *Characteristics of the leader* (gender, age, and so on…): these give details about the nature and character of the network.
- *Number of direct links with companies (for the manager)*: this is displayed in the Dirigeant.com site's mapping by the number of *manager-company links* that the manager maintains with specific companies. When there were many leaders, we only took into account the shared activity once. As specified above, we will only consider non-redundant links due to this approach.
- *Number of indirect links with individuals (for the manager)*: in the mapping of the 'Dirigeant.com', this indicates the number of indirect links a manager has with certain people (manager-company-manager links). All these individuals serve as the examined manager's co-agents for the companies they both work for. We only considered the connection between the leaders once in situations when there were many leaders. As done previously, with this approach, we will examine only non-redundant links.
- *Number of total (firm) links with firms*: this sums all connections, both direct and indirect, to businesses.
- *Number of total (company) links with individuals*: this includes all connections to individuals, whether direct and indirect.
- *Margin rate*: EBITDA to turnover is compared in this ratio. It displays the percentage gain or loss that a business has experienced.
- *Current assets/Debt*: this ratio illustrates the firm's capacity to satisfy its financial obligations and withstand challenging economic conditions.
- *Leverage*: total debt to equity is expressed as a ratio here. In relation to its equity, it assesses the company's capacity to pay off debt.
- *Ratio of activity by customer delay*: this determines how long on average the company's suppliers' or customers' debts take to be paid.
- *Labour productivity ratio*: this represents the amount of goods or services produced for each unit of the production factor used. It enables the performance of the productive system to be measured.
- *ROA (Return on Assets)*: this computes the net income-to-total-assets ratio as a percentage. It is a measure of the company's profitability. It shows the capacity of the business to use all its resources to get a result.
- *ROE (Return on Equity)*: the ratio between "net income" and "equity" measures how profitable the business is.
- *"Margin" for ROE*: this ratio represents the margin between the company's "turnover" and "net income".
- *"Rotation" for ROE*: this is a ratio between "turnover" and assets. It illustrates how a company's assets and operating revenues are related.
- *"Leverage" for ROE*: this measures the proportion of "equity" to "total assets". It stands for the return on investment made by shareholders in the business.
- *Repayment capacity*: this represents the ratio between "net income" and "total debt". It indicates the capacity of the business to pay back its debt.
- *Debt ratio*: this is the ratio of the company's debt to its total liabilities, or the "sum of equity and debt", or "equity plus debt". It gauges a company's debt load in relation to its equity.
- *Cash/debt*: this number represents the company's debt to cash to debt ratio. It is used to determine how much cash can be used to finance short-term debt.

3.2 Descriptive statistics

The primary indicators have been examined for position and variability for the sample's variables. The descriptive analysis can be found in the Annex.

3.3 Table of correlation between variables

The relationships between each of the variables in the table were examined. We then chose the variables for the model based on the correlations that were most significant (see Correlation table in the Annex).

3.4 Choice of variables

For our study, we considered several model assumptions that have a good indication of the company's performance as a dependent variable. It appears that ROA or ROE are not the best variables to use when building a useful prediction model. We came to this conclusion after testing several models with these variables as a dependent variable and various combinations of executive characteristic variables. This is because none of the models produced significant values for the regression parameters. (F-test with $p > 0{,}01$).

The variable "turnover" or, more precisely, its mathematical transformation *(log(turnover))*, as well as a set of variables that represent the traits of managers, have also been set up in another model. Additional variables have been added to this model to indicate the unique traits of the company. The dependent variable *log(turnover)* was chosen from those characterising the managerial traits and from among the other control variables helpful for refining the model (see in the Annex). It was found to produce the best model. We utilised the Bayesian Information Criteria to choose the model that would best fit the data. Indeed, we found multiple models using *log(turnover)* as the dependent variable (we selected the model with a lower BIC, see in the Annex). We will go into great depth about this model and assess its consistency in terms of the traits of a linear model.

Two detection units (*Pack services, top services, top transports, and BMS Transport*) were left out in order to preserve the consistency of the data since they produced anomalous residual values (the coefficient *R2 adjusted* increased from 0.768 to 0.807 with the exclusion of extreme values).

Table 2 Adjustment quality factors

Variable	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	5.488	0.045	121.118	<2e-16 ***
added_value	0	0	7.877	5.32e-11 ***
employees_number	0.006	0.004	1.724	0.09.
indir_links_w_individuals	0.02	0.023	0.861	0.393
company_age	0.002	0.002	0.916	0.363

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

3.5 Descriptive statistics

We began by examining the descriptive statistics for each variable (the table can be found in the Annex) after choosing the independent factors that could provide a reliable prediction for the dependent variable.

3.6 Correlation matrix

According to the basic hypothesis, where the correlation coefficient $_r$ varies between 1 and -1, the variables are negatively correlated (perfect correlation) when $r = -1$ and they are uncorrelated when $r = 0$. The correlation between the number of employees and the company's turnover (0.691) is therefore confirmed to be close to 1, which denotes a significant correlation between the variables, according to the correlation matrix displayed in the Annex.

3.7 Multicollinearity statistics

It is possible to emphasise the absence of multicollinearity factors through the observations made in the case of the correlation between the variables. The study of variance factors, or VIF (Variance Inflation Factor), which indicates how much an explanatory variable may be explained by the other explanatory variables in the equation, can also be used to diagnose multicollinearity. In general, multicollinearity is high if VIF > 10. The low VIF in our situation for each variable supports the idea that there is no multicollinearity. See in the Annex contains a list of these values.

3.8 Adjustment quality factors

The *R2* index can be used to check the model's validity as well as the quality of the fit. Since we are dealing with at least two explanatory factors, the coefficient of determination *ADJUSTED* in the multiple regression model represents the percentage of variability explained by the explanatory variables.

In this instance, the index *ADJUSTED* has a value of 0.807, indicating that the model closely matches the observed data (see Table 1). The estimated value for each regression coefficient and the probability for the two-tail test *t*, which demonstrate its significance, are displayed in the following table. The test displays all the model parameter's significant values (see Table 2).

The results of the multiple regression model coefficients should be viewed as partial regression coefficients, which means they can be used to measure changes in the response variable *y* in response to changes in one of the explanatory variables while keeping the other explanatory variables constant. In our hypothesis, we want to analyse the variation in

performance. Thus, we may declare that, for a given firm, a rise or decrease of one unit of each independent variable is equal to the value of the coefficient, others remaining constant. Constructed in this way, the model can analyze and compare the same conditions for different societies.

3.9 Analysis of variance and testing F

The presence (or absence) of a meaningful link between the dependent variable and all explanatory variables can be estimated once the model's validity has been established. Given that there are two explanatory variables, the following null hypothesis and alternative must be specified:

- $H0 : B1 = 0$ (The dependent variable and the explanatory variables do not have a linear relationship)
- $H1$: $atleastoneBj \neq 0$(The dependent variable and at least one explanatory variable have a linear relationship)

What if:

- $p - value \geq 0{,}05$ (The null hypothesis cannot be refused)
- $p - value < 0{,}05$ (The null hypothesis must be rejected)
- To solve the problem of hypothesis verification we used the F test (see Table 3).

3.10 Diagnosis of residues

The discrepancy between the observed value and the estimated value of y is referred to as a regression residue. Using the first graph of the residuals, the graphical method enables us to verify that our results agree with the basic (fundamental) assumptions.[6] It is feasible to tell from the scatter plot whether the residues exhibit a trend, with the predicted values of y having a discernible structure. The points (above and below average) are dispersed randomly in space. The graph demonstrates that the homoscedasticity theory is true (See Figs. 8 and 9).

The structure of the residuals will appear narrow towards the origin and wider towards the outside (megaphone structure) in the case of heteroscedasticity with a variance of the growing residuals, and conversely, the points will experience a shrinkage to emphasise how the variance decreases with the increase of y. An evaluation of the model's quality

[6] Fundamental assumptions:Linearity (the dependent variable is linked to the independent variables by a linear function).Normality (the residue distribution is a Gaussian distribution).Homoscedasticity (the residues' variance is constant).Independence (residues are independent).

Table 3 Analysis of variance and testing F

Df	Sum Sq	Mean Sq	F value	Pr(> F)
1	9.55	9.55	279.932	< 2e-16 ***
1	0.210	0.21	6.165	0.016 *
1	0.05	0.05	1.454	0.232
1	0.029	0.029	0.838	0.363
64	2.183	0.034	NA	NA

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

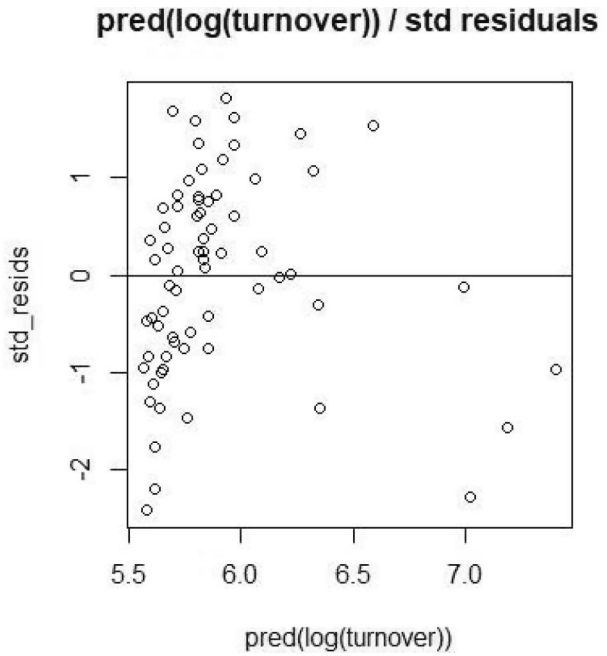


Fig. 8 Scatter plot of residuals

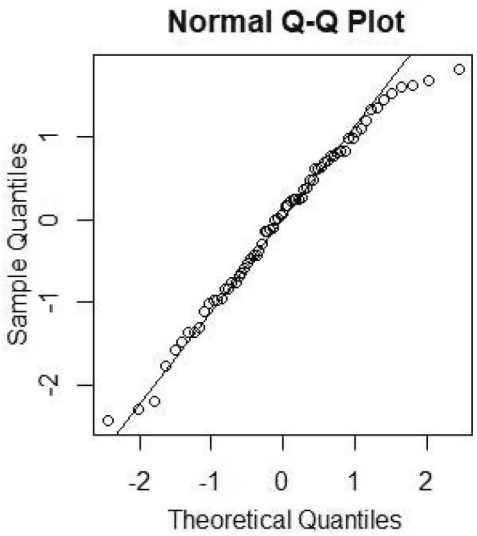


Fig. 9 Q-Q Plot

of fit can be shown graphically using the quantile-quantile plot shown below. It contrasts the residual distribution with a normal distribution. Running a linear model is a reasonable assumption if the former occurs after the latter.

3.11 Classical model assumptions and fundamental property of homoscedasticity

The model must adhere to standards to be declared as being used appropriately. For instance, if a variable is missing from the analysis, the model is said to be prone to a specification mistake. Therefore, the model must first be deemed appropriate and adequately described. All inference techniques may be impacted by distortions in coefficient estimates due to specification mistake. It does not appear that our situation violates the fundamental feature of homoscedasticity, which presupposes that the variance of data in space is equal. The F-test diagnosis, which assesses whether the analysed variables have precisely the same variance, can be used to analyse the homoscedasticity condition.

In line with the observed values, the following graph displays the confidence interval for the predicted values. We observe that the points are almost all extremely close to the line and that they are all within the confidence interval, as already shown by the R2 index (See Fig. 10).

3.12 Outcome

We can draw the conclusion that the factors examined are reliable indicators of the *turnover* variable. One measure that is positively correlated with turnover is the number of indirect ties with specific individuals. Positive correlation exists between *turnover* and the size of the business (number of employees). The adaptability of the model was increased by the addition of two more variables related to accounting items and business seniority. Therefore, we draw the conclusion that managers' networks mostly affect company robustness (turnover, net income) and only marginally firm performance (financial ratios) for the enterprises in the sample.

3.13 Introduction of the PCA model

To determine the most crucial aspects of firm characteristics, we employed the Principal Component Analysis (PCA), a statistical method designed to combine a group of variables based on their relationships into a small number of latent dimensions that most effectively capture the capabilities of business leaders.

3.14 The data matrix

We arranged the information gathered from secondary analysis in a matrix of business variables. This matrix, of $n \times p$ dimensions, produces row and column vectors of different types. In the columns of the basic matrix, we have placed the features of the statistical units, namely the variables, and in the rows of the basic matrix we have placed the objects, namely the observation units and statistical units, in our case the firms of the field of research. In each row of the matrix the information $_p$ relating to an i-*th* statistical unit is present, yet each column includes the modalities that a j-*th* unit assumes.

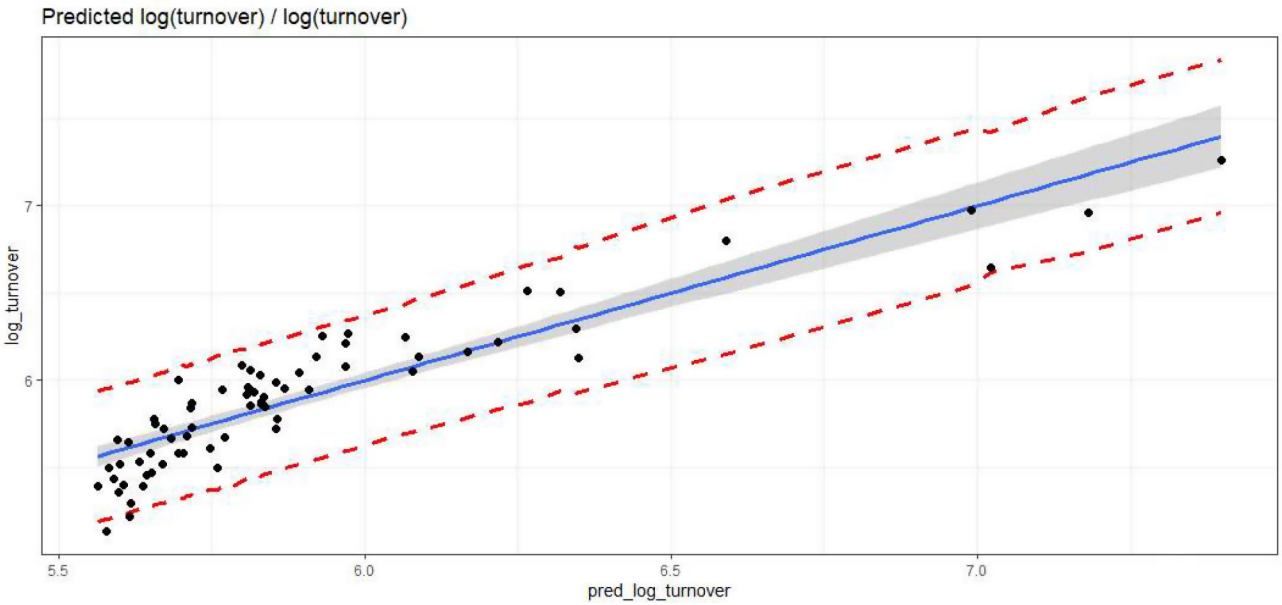


Fig. 10 Prediction interval for expected values

3.15 The correlation matrix

The correlation matrix serves as the foundation for the study of the primary components. The *ratio* between the covariance and the product of the standard deviations of the two variables yields the correlation coefficient between two variables. The analysis of the correlation matrix among all the basic variables allows us to have a first understanding of their interactions. Our expectation is to perform a decent synthesis of the initial data with a smaller loss of information. For PCA to be successful, the presence of a sizable proportion of common variances among the initial variables is required. This is true when the correlation coefficients between the variables are neither too low, as this would result in duplicate information, nor too strong, as the independence of the variables would make it difficult to produce an effective synthesis.

The correlation matrix between the variables examined below enables a preliminary evaluation of the links that already exist between the studied outcomes. While an individual examination of each experiment could yield the analysis of correlation linkages, it would produce a considerable number of graphs. As we shall see, the PCA seeks to minimise this issue and carry out an analysis within a single Cartesian plane, so streamlining the interpretative issue (See Table 4).

The row and column variables' association with one another is represented by the diagonal of the matrix, which has all values equal to 1. With respect to column variables, each row variable exhibits a positive or negative correlation as well as a low or high modality. The correlation between the variables "*employees number*" and "*turnover*" is examined as an example: its value is 0.691, and it is well known that the correlation coefficient varies between $-1 \leq r \leq 1$. As a result, we can infer a significant positive association. The correlation matrix can be viewed both by row and column, which immediately provides useful information. We ignore the correlations between "*number of links*" that are unmistakably related to one another. Additionally, we can observe that the number of direct connections, the number of individuals, the number of employees, and the seniority of the organisation are all strongly connected with "*turnover*".

Table 4 Analysis of existing relationships between observed variables (partial)

	Employees_number	Turnover	Company_age
Employees_number	1	0.691	0.276
Turnover	0.691	1	0.254
Company_age	0.276	0.254	1
Mandates_number	0.497	0.371	0.087
Leader_age	0.09	-0.018	0.417
Dir_links_w_companies	0.495	0.37	0.083
Indir_links_w_individuals	0.502	0.299	0.359
Dir_links_w_individuals	-0.046	-0.025	0.128
Indir_links_w_companies	0.495	0.37	0.083

3.16 Principal component analysis: objectives and phases of the method

Factor analysis techniques include Principal Component Analysis, which was created by Pearson in 1901 [45] and then developed by Hotelling in 1933 [46]. PCA is a multidimensional technique that identifies the key elements that constitute the fundamental framework of the interactions seen in the correlation matrix using a wide variety of correlated variables. In other words, the PCA offers a smaller set of correlated variables that can account for a sufficient portion of the information included in the source variables. Therefore, it involves lessening the number of initial variables rather than only eliminating redundant data that was produced through the observation of the connected variables. The correlation matrix serves as the procedure's starting point because the PCA's goal is to create new constructs from variables that are mathematically correlated. Thus, the primary elements are identified. Afterwards, the same will be employed as analysis dimensions to check for any potential relationships between the original variables and the considered observations. The crucial phase of the analysis will involve evaluating the method of choice for adaptability. Below, a more thorough illustration of the various phases will be provided.

3.17 Choice of eigenvalues and eigenvectors

Eigenvalues are used to describe component variance. The explained variance for each component is given by the ratio of each eigenvalue to the total eigenvalues of all components. Finding the correlation matrix's eigenvalues is consequently necessary. As many eigenvalues as there are x variables are obtained. The variance of the principal component 1 will be the highest eigenvalue since it corresponds to the dimension w with the highest variance. The variance of principal member 2 will be the second eigenvalue, and so on for n eigenvalues, in descending order. The variance that the greatest eigenvalues in our example explain is determined by their connection to the sum of eigenvalues, as was already mentioned. The most important values are those greater than 1.

The matrix (line vector) of the coefficients that multiply the old variables in the linear combination to produce the

new variables is calculated for each eigenvalue. The eigenvalue matrix, also known as the rotation V matrix, is the matrix that contains each eigenvalue that was initially determined as its row. It is required to confirm that the eigenvalues' length and degressive product in the matrix are both equal to 1 (See Table 5).

The eigenvalues, the proportion of total variance, and the cumulative percentage are all listed in the table above. The table's eigenvalues are arranged in descending order by dimension, highlighting how crucial relative factors are for understanding data variability. The factor (4,33) corresponding to the highest eigenvalue expresses roughly 48,11% of the total variance, followed by the second factor (1,437), which expresses roughly 15,97% of the total variability, the third (1,217), which expresses roughly 13,53% of variability, and the fourth (1.017), which expresses roughly 11,30% of variability. The first four elements' combined variance expresses a total variance of 88,90%. The number of variables from which these factors have been extracted is equal to the total of the eigenvalues when analysing a correlation matrix; in our case, this number is precisely 9, and the average eigenvalue is equal to 1.

3.18 Selection of major components (axis or factors)

We begin with p variables in the analysis of the PCA with the goal of synthesising them into a smaller number. Therefore, analysing less data than the original is the objective. Different criteria are employed to accomplish this, the simplest of which is to maintain all components with eigenvalues greater than 1, also known as the *Eigenvalue-one Criterion* (or *Kaiser Criterion*). This can be the case for the four underlined values, which already identify 88,90% of the overall variability. Referring to the scree-plot, which was in this case produced using the *factoextra* package in R, is another way for figuring out how many factors need to be interpreted (See Fig. 11).

It specifically compares the number of components versus the percentage of explained variations (sorted from largest to smallest). The recommendation is to locate a point on the graph where the values appear to level off and form an "elbow"; at this point, the leftmost components should be taken into consideration as relevant. This stage appears to be achieved in our situation on *Dim.4*. Even while the following criteria make it possible to uncover the most obscure parts of the observed event, it is crucial to keep in mind that their interpretation may become more difficult from a "methodological" standpoint. Because their explained variability is lower than that of the first factors, it depends on the habit (See Table 6).

3.19 Factor coordinates of variables (variable-factor correlation)

The factorial coordinates of the variables are displayed in the table. As the analysis takes into consideration the correlation between the same variables, these data can be used to infer the relationship between each variable and its corresponding factor. The first key variable can synthesize the data to the greatest extent with the lowest information loss during spatial reduction. The angles at which the variables are located on the new axes correspond to the correlations between the old and new variables. We should keep in mind that the new axes are determined by the eigenvalue, which is the decreasing number that, when multiplied by an angle, produces its value, i.e., an axis with direction, intensity, and direction. The largest eigenvalue will determine the primary direction, and it will be followed by all eigenvalues with smaller values. The largest eigenvalue corresponds to radius 1 of the factorial circle 1–2 (Huyghens' general theorem) (See Table 7).

Given that the variables "*mandates number*" and "*links with companies*" can be regarded as the variables with the greatest representative "weight" of the factor and given the correlation between the original variables and the components obtained by the analyses, it is possible to consider "*links with enterprises*" as the primary dimension. The second factor could be interpreted as the seniority of the enterprise (manager and company age are more important); the third factor could be interpreted as the "solidity" of the enterprise (its composition has primarily been influenced by the number of employees and turnover); and finally, the

Table 5 Eigenvalue matrix

Dim.	Eigenvalue	Variance.percent	Cumulative.variance.percent
Dim.1	4.33	48.111	48.111
Dim.2	1.437	15.966	64.078
Dim.3	1.217	13.526	77.604
Dim.4	1.017	11.297	88.9
Dim.5	0.525	5.830	94.731
Dim.6	0.319	3.539	98.27
Dim.7	0.155	1.725	99.994
Dim.8	0	0.005	100
Dim.9	0	0	100

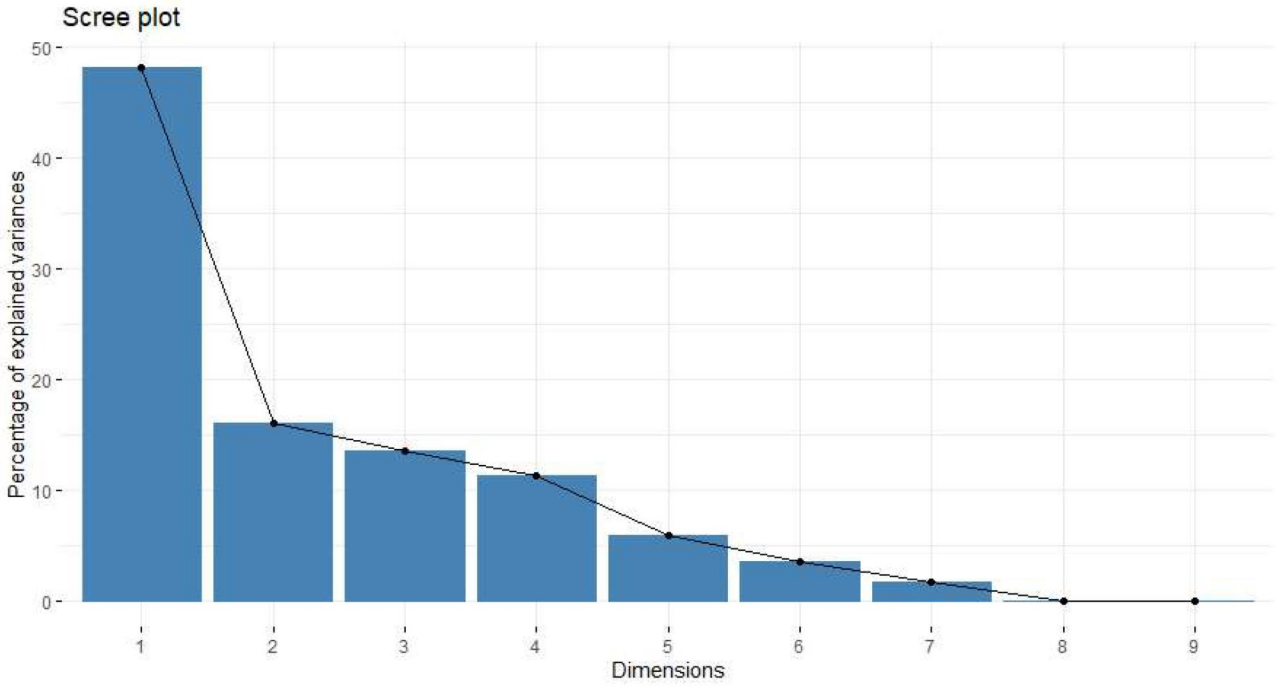


Fig. 11 Scree-plot

Table 6 Relationship between the respective variable and its factor (partial)

Variable	Comp.1	Comp.2	Comp.3	Comp.4	Comp.5	Comp.6	Comp.7
Employees_number	0.334	0.111	0.497	NA	0.177	0.709	0.294
Turnover	0.267	0.101	0.633	0.183	0.287	-0.548	-0.320
Company_age	0.142	0.688	NA	0.588	-0.212	0.310	NA
Mandates_number	0.454	-0.202	-0.159	NA	-0.137	0.195	NA
Leader_age	0.114	0.517	-0.270	-0.541	0.565	NA	-0.177
Dir_links_w_companies	0.454	-0.198	-0.169	NA	-0.137	0.184	NA
Indir_links_w_individuals	0.407	0.106	-0.206	0.205	-0.340	0.298	-0.731
Dir_links_w_individuals	NA	0.326	-0.381	0.771	0.325	0.208	NA
Indir_links_w_companies	0.454	-0.198	-0.169	NA	-0.137	0.184	NA

Table 7 Contribution of variables as a percentage (partial)

Variable	Dim.1	Dim.2	Dim.3	Dim.4
Employees_number	11.155	1.224	24.718	0.836
Turnover	7.14	1.017	40.075	3.331
Company_age	2.005	47.377	0.967	0.99
Mandates_number	20.571	4.062	2.528	0.779
Leader_age	1.292	26.729	7.282	29.296
Dir_links_w_companies	20.602	3.925	2.848	0.532
Indir_links_w_individuals	16.574	1.123	4.24	4.215
Dir_links_w_individuals	0.06	10.62	14.495	59.49
Indir_links_w_companies	20.602	3.925	2.848	0.532

fourth factor could be interpreted as the connections the enterprise has with its customers.

Because the second axis is at an angle to the first, they cannot be associated. Thus, we will be required to employ the part of intelligence that the first axis does not consider.

3.20 Contribution of variables

The distortions in the configuration of the originating points are dictated by the projection in the reduced subarea; the projection axes are chosen based on the initial variable values recorded on the various units. Therefore, it is important to evaluate the quality of representation for each unit in terms of the absolute and relative contributions of the variables. Absolute contribution or relative contribution can be used to determine whether the values depicted are reasonably close to reality. These two conclusions are reached by comparing the observed and expected variables' differences.

According to the squared coordinate, in relation to the inertia of the associated axis, and eigenvalues, the term "absolute contribution" denotes the contribution made by the variable in the building of the factorial board axis.

Remembering that the projection may not always be successful in recreating the initial distance between two locations, relative contribution or cosine squared reflects how effectively the variable is represented on the axis. Calculating the square of the cosine of the angle created by the vectors corresponding to the original point and its projection is necessary. Therefore, the representation of the variable is more accurate the closer the value of the angle is to 1. The highest values have been highlighted in bold. This measure ranges from 0 to 1, where values closer to 1 indicate stronger similarity (See Table 8).

The variables "*number of direct links with companies*" and "*number of indirect links with firms*" in our situation are the ones that are most accurately representative. The table of the factorial coordinates of the observations can be found in the Annex.

3.21 Contact information for observations: the calculation

The analysis of the location of companies (or observations) or the observation of the location of variables can both be used to find the place of a dimension that can efficiently synthesise the useful structure present in the matrix of the original data. It is important to note that, even though there is a known difference between the two locations, the eigenvalues produced from the two studies correspond. This effectively tends to prove that the individual primary components are the same. The interpretation of the significance of each variable is made possible by the analysis of the locations of enterprises (which we will refer to as "observations"). On the other hand, the study of the variables' locations enables the control of the order that each unit's variables take.

We will attempt to provide examples later to show how the calculation of observations is anchored to particular sections. Starting with the values on the correlation matrix, which are arranged successively in descending order such that the values of Dim.1 are greater than Dim.9, we can eventually see the variability explained (as in the passage above). This is similar to the way variables are calculated. It is crucial to assess whether our eigenvalues satisfy the requirements of orthogonality and unity throughout this phase. By combining the matrix of the modified $_{x}$ data and the matrix of the observations on the new axes (*Dim.1* and *Dim.2*), the outcome of such an observation enables the calculation of the coordinates of the observations.

Table 8 Square of the cosines (partial)

Variable	Dim.1	Dim.2	Dim.3	Dim.4
Employees_number	**0.483**	0.018	0.301	0.009
Turnover	0.309	0.015	**0.488**	0.034
Company_age	0.087	**0.681**	0.012	0.01
Mandates_number	**0.891**	0.058	0.031	0.008
Leader_age	0.056	**0.384**	0.089	0.298
Dir_links_w_companies	**0.892**	0.056	0.035	0.005
Indir_links_w_individuals	**0.718**	0.016	0.052	0.0429
Dir_links_w_individuals	0.003	0.153	0.177	**0.605**
Indir_links_w_companies	**0.892**	0.056	0.035	0.005

3.22 Graphs of factorial coordinates

Finding factors is frequently made easier by factorial coordinate graphs. The circle's segment variables will all point in the same direction if they are positively correlated with one another, which means that when one of them assumes a high value as a unit, the others will follow suit. A negative correlation exists between two variables $-i$ that move in the opposing directions. They will also be independent of one another when placed perpendicularly.

A factorial design 1–2 is taken into consideration in the graph, which explains why there are 64,1%. It is possible for us to make certain considerations given the prior evidence (See Fig. 12).

In this instance, we see that the output strategy will produce a circle with a unit radius. The upper factor coordinate, which is, as we have indicated, the correlation between the variable and the factor, will be equal to or nearly equal to 1 because the current analysis is based on correlations. The meaning of the coordinates is correctly reproduced by reading the correlation circle. Therefore, the more representative the current coordinates are, the closer the points are to the circle's edge. All coordinates will be shown inside the circle since the sum of all factorial coordinates, or the squared correlations between the same and the factors, cannot be greater than 1. The Varimax solution is then "turned" to produce a better representation, allowing for the determination of the ideal pairing of the initial variables and factors. The outcomes of the Varimax rotation are shown in the Annex (See Table 9).

3.23 Observations: a graphical representation

In this sub-section we investigate the distribution of points (71 enterprises) for the proposed factorial design 1–2, in which the location of the sectioned *Rn* firms is deferred. The analysis of the graph shows that, as in the prior instances, the higher a point is on the graph, the more it will be characterized by values, better respect for the factor being considered, and the further it moves away in positive or negative from the averages. If located in the background of the graph, the worst values will be displayed (See Fig. 13).

Fig. 12 Factor coordinate graph

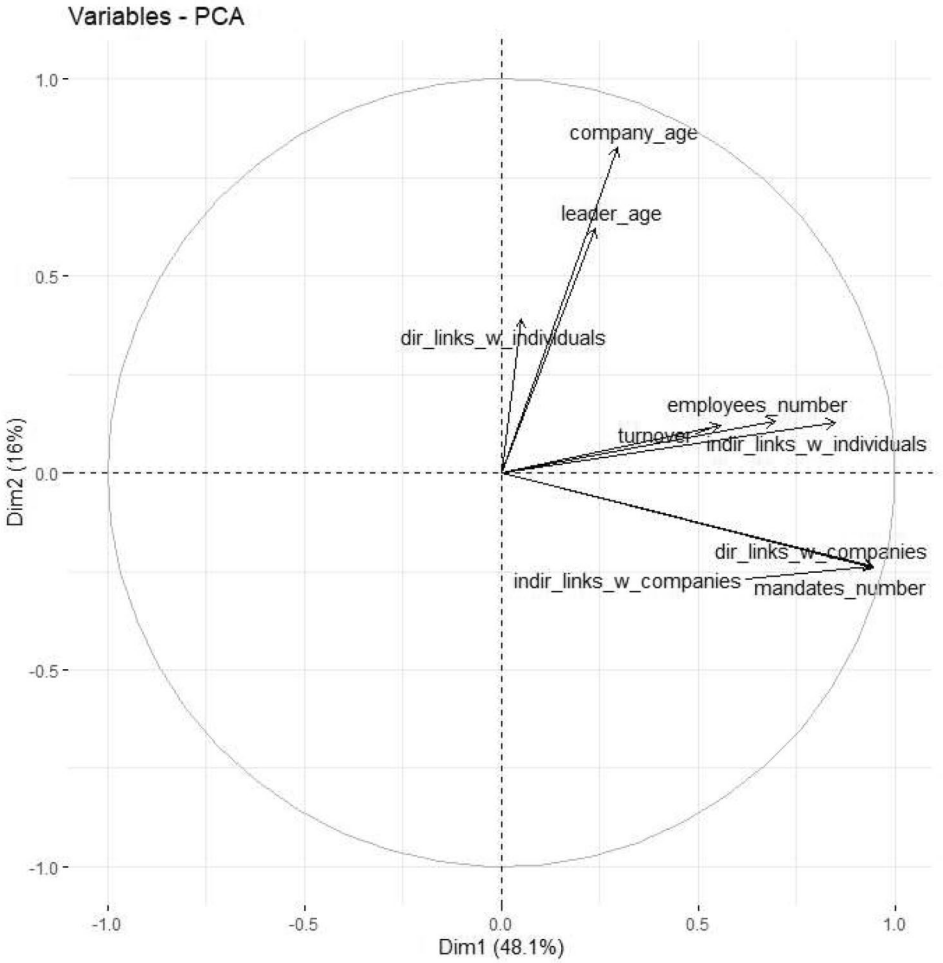


Table 9 Contribution of variables after Varimax rotation

Variable	RC1	RC2
Employees_number	**86.82**	13.18
Turnover	**85.04**	14.96
Company_age	2.54	**97.46**
Mandates_number	**99.54**	0.46
Leader_age	3.26	**96.74**
Dir_links_w_companies	**99.60**	0.40
Indir_links_w_individuals	**89.38**	10.62
Dir_links_w_individuals	0.28	**99.72**
Indir_links_w_companies	**99.60**	0.40

3.24 Model conclusions

The set of variables in the database allows for the identification of two fundamental components (two synthesis variables) that efficiently synthesise the initial variables from the turned solution. A primary element that enumerates the variables *employees_number*, *mandates_number*, *turnover, dir_links_w_companies*, *indir_links_w_individuals* and *indir_links_w_companies*; and another that includes details on *company_age*, *leader_age* and *dir_links_w_individuals.*

The analysis' findings thus provide the first proof of our work's basic hypotheses: we gauge the stability of businesses and the management network using several factors that, through factor analysis, are identified in a single synthetic indicator (*Dim.1*); the enterprise's seniority in a second indicator (*Dim.2*). The number of direct ties to people, which falls into the second category rather than the first, appears to be the sole outlier.

Mathematically, we have therefore reached a precise separation between the two separate parts of the object, while still accounting for a 36% loss of information.

3.25 Search for outliers

We attempted to use a different model to lessen information loss and enhance our PCA analysis. This time, we tried to exclude some outliers, or companies whose coordinates in the new space suggest a point that is highly dissimilar from the other units of analysis.

Using the *pca.outlier* function from the *mt* library of R, we evaluated the Mahalanobis distance to achieve this (which differs from the Euclidean distance in that it takes

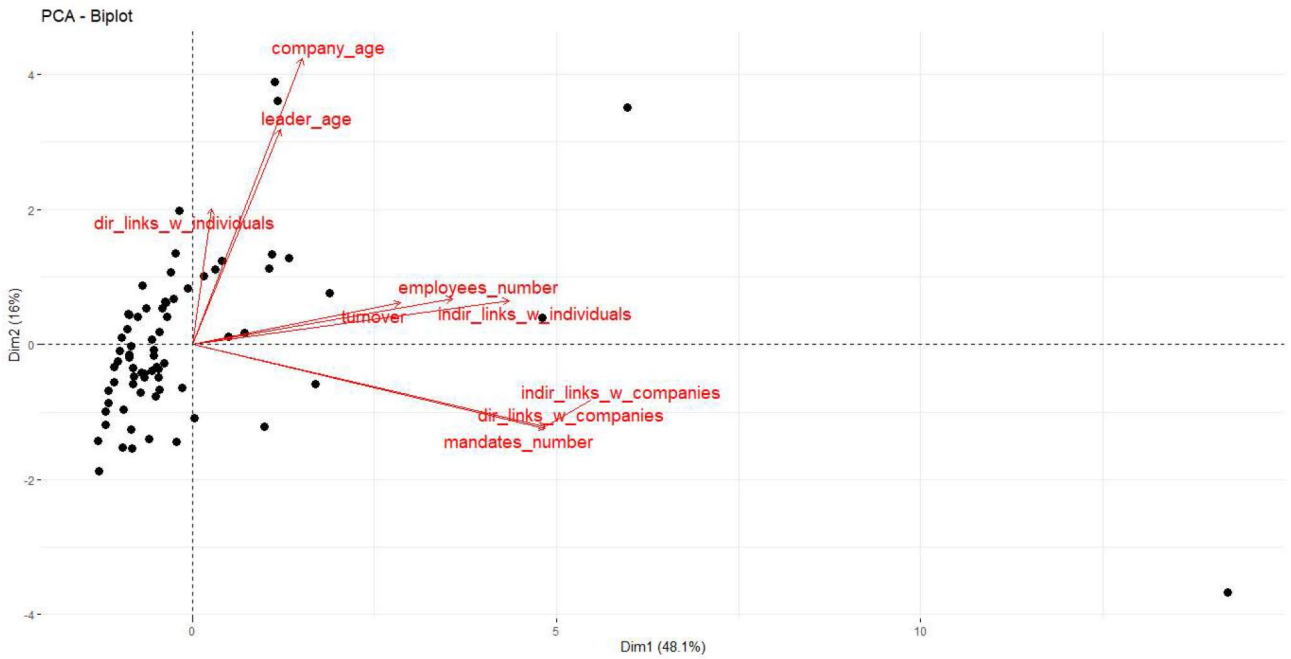


Fig. 13 PCA - graphical representation of variables and observations

into account the correlation between variables; see the Annex) (See Fig. 14).

In order to achieve the highest level of explainability, we then tried to eliminate each individual observation that was indicated one at a time, followed by combinations of them. Even with our best result, information loss was only reduced by less than 1% (from 77,6% to 77,9% at *Dim.3*). We thus concluded that removing the outliers would not have made a difference in our scenario.

4 Conclusions

The importance of managers within enterprises has significantly expanded in recent decades. This is partly because the capital owned by the founding entities of large firms has decreased, making it necessary for small and medium-sized enterprises to choose managers who operate in the best interests of all shareholders. In order to survive in an ever-shifting market characterised by an unpredictable demand, SMEs have increased the amount of responsibility entrusted to managers. Thus, given their heightened importance within companies, they have naturally come to utilise all the resources at their display, including, above all, their network relationships. Indeed, networks have been understood to be a key tool that individuals can turn to when dealing with instability and obstacles [4]. The deeper and more diverse the network is, the more extensive and beneficial the resource and information sharing between the network nodes will be. As networks have been connected to growth, innovation, and sustainability, it is evident that today's companies are looking for leaders with rich social ties. However, we have also shown that the way in which networks are actually used to the advantage of the company depends on the personality of managers. Some will be able to gather crucial information from their social circle, while others will be less inclined to do so. Personality characteristics such as extroversion are to be acknowledged as positively influencing the way in which networks are built and then utilised: indeed, extroverted managers tend to invest more time in cultivating their networks, and they also tend to be more trustworthy than others [25, 26]. Thus, company performance and the management's characteristics are inextricably linked, as underlined in Anggadwita and Mustafid's framework [11].

The theoretical backbone of our research has been the dependency network approach. We have chosen to study networks by looking at nodes and links (i.e., the network actors and their relationships) in order to comprehend how they influence each other, and which dependencies can arise due to resource imbalances [15, 17]. Focusing on the issue of dependencies, we have chosen to also rely on the assumptions of the Resource Dependency Theory [27] and we have tried to understand them considering some of the many principles of network theory. This, together with the literature of previous authors on similar issues to ours, has allowed us to formulate our hypotheses.

The aim of our research has thus been to elucidate the critical role of networks within SMEs and understand if and how these influence the overall performance of the

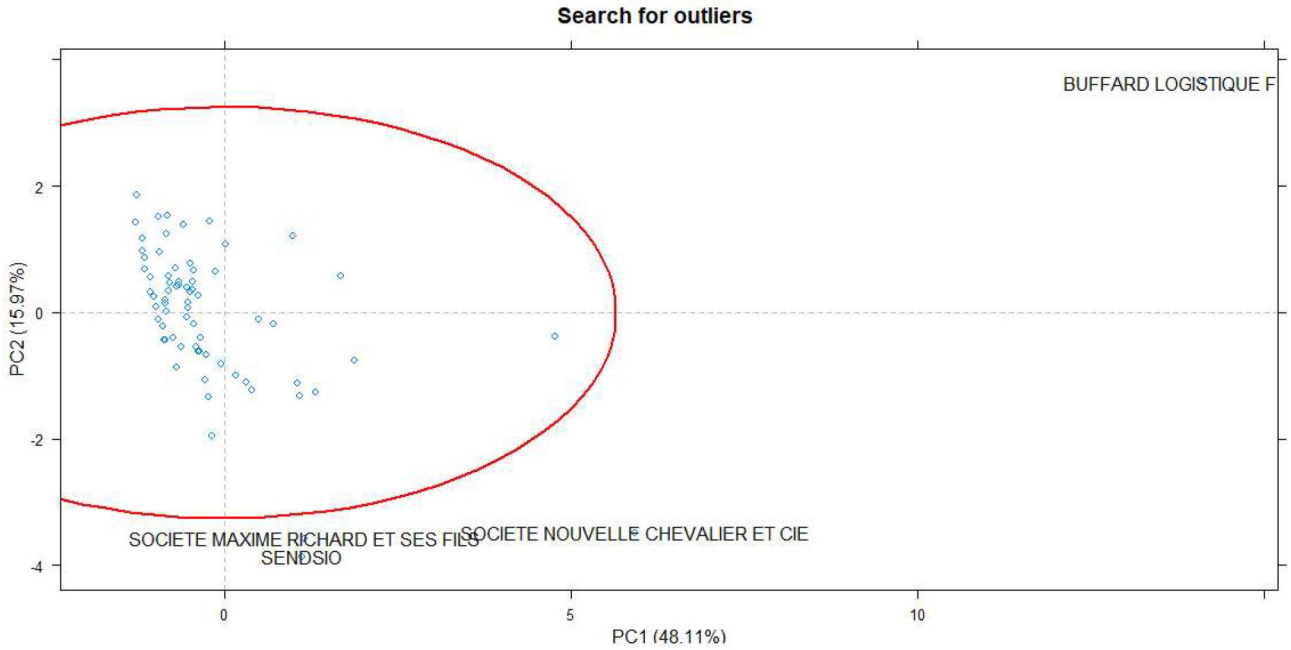


Fig. 14 Search for outliers

companies in our sample. Prior studies have examined this. Soetanto et al. and Yeniaras and Unver [4, 13] have shown that networks foster resilience, growth, and innovation. Gharsalli, Jackowicz and Kozłowski [2, 3] have highlighted how privileged network ties can give companies unparalleled advantages in terms of their financing. These authors, as well as others, have shown the significance of social networks and how they affect a company's characteristics, such as increased revenue, decreased costs, higher net profit, improved executive compensation, etc. In addition to this, networks can also be beneficial to the managers themselves, who can leverage their social ties to obtain higher remuneration, take on more responsibilities in the company they work for, or accept management positions in other companies, thanks to word of mouth and recommendations [23]. Thus, managers are increasingly seen as a new asset for companies, and they are not only anymore compensated for the knowledge that they possess, but also for the advantages that their networks can provide the company.

In our work, we chose to select a number of SMEs from the freight transportation sector in the Paris department. Given the above-mentioned findings of the studies conducted on the subject, we hypothesized that broad and diverse managerial networks would significantly foster firm robustness and that they would greatly influence the performance for the companies in our sample. However, our evaluation of company performance (through certain financial measures like ROE) has yielded inconsistent outcomes. In fact, virtually little association exists between network characteristics and performance measures in our investigation. A positive association between executive resources and "bottom line and turnover", particularly the transformation *log (turnover)*, has been highlighted by our statistical study. It is quite intuitive to understand why managers' private resources can help with sales and cost-cutting, but more difficult to grasp when it comes to how they can boost business performance. Therefore, we conclude that for the selected enterprises in the freight transportation industry, managers' networks mostly affect company robustness (turnover, net income) and only marginally firm performance (financial ratios). Through the PCA, we also find support for our initial hypotheses: we can quantify the performance of companies using a number of variables and visualize these in a bi-dimensional graph, where the first dimension describes the robustness of the company (turnover and number of employees) and the manager's network (therefore, the manager's links with people and businesses), and the second explains the seniority of the enterprise (company and leader age).

However, this study also presented some challenges, especially in terms of data collection. Our initial research on the previously mentioned websites yielded a substantial number of companies. Nevertheless, when we selected the criteria to construct our dataset on 'Societe.com', approximately one thousand companies were excluded due to a lack of any financial data, leaving us with about 80 companies. Subsequently, an additional 10 companies were excluded manually due to other missing data, including financial information and details about the manager, which were crucial for our study. This aspect posed a limitation to our

research by reducing the representativeness of the considered sample. Consequently, we believe that future studies would benefit from greater availability of public financial data about companies.

Therefore, we can conclude that although networks influence the performance of freight transportation companies, this effect is less significant than expected. This finding only gives partial confirmation to our initial hypotheses. However, since we have still identified a positive association between managerial networks and the performance of the selected enterprises, the value of networks should not be underplayed by managers of SMEs. As we have shown throughout this study, networks can function as a "safety net" for companies; consequently, individuals at both top-executive and non-executive levels should always strive to cultivate and diversify their social ties, so that companies can benefit from maximum resources and information to achieve optimal growth.

Annex

The table on the following page displays the findings of empirical research conducted by various authors in various years and locations. The table is divided into seven rows. The first lists the authors' names and the year of publication; the second lists the name of the nation in which the authors conducted their research; and the third lists the independent variables in their analysis. The authors' findings are listed between the fourth and seventh rows.

Géraudel and Chollet [47] studied Canadian enterprises and discovered a significant correlation between the quantity of direct and indirect relationships with people and company profit They demonstrated that turnover and net profit increase in direct proportion to the number of parties with which managers have social ties. Effects may be connected to each other, but they are not a given. For example, revenue may have increased because of higher sales, and net income may have increased because sales, or expenditures, may have diminished or spiked. An increase in revenue or an increase in net income are both benefits that networks can bring. Authors Ndangwa [48] conducted interviews with a selection of Cameroonian leaders and reached a similar conclusion. The performance of the business (as defined by revenue and net profit) and the strength of the connections within the executive network were both measured by them in their study. They came to the conclusion that increasing performance also increases network intensity. More profit translates into more significant connections for the company's executives. We can also mention the authors' discovery of a negative correlation between the performance of the company and its age as another intriguing finding. Moreover, Collins and Clark [23] conducted research on how managers' social networks influence a company's performance. Their results were consistent with those of the studies above. They demonstrated that both internal and external networks can offer significant advantages to technology companies in the United States, especially in terms of valuable information. They also examined human resources (HR) practices, and found that these can have a substantial impact on strengthening social networks within a company. Finally, Vigliano and Barré [49] carried out research using a sample of French businesses, where they centred on top executives' remuneration. They came to the conclusion that executive salary and firm size have a positive association. The kind of positive association between the independent variable—the number of connections made directly and indirectly with other people—and the independent variable, or the number of connections made by the leader, is the one that matters the most to us.

Authors	Gèraudel M. and Chollet B. (2009)		Ndangwa L., Sonna F. and Djeumene P. (2007)	Collins C. and Clark K. (2003)	Vigliano M. and Barré G. (2010)	
Country of analysis	Canada		Cameroon	United States	France	
Variable explained	Number of indirect connections with companies	Number of direct and indirect links with individuals	Performance (CA, Net income)	Number of direct and indirect links with individuals	Size of firm	Number of direct and indirect links with individuals
Explanatory Var. #1Effet expected	Number of indirect connections with people +	CA +	Intensity of network links +	CA +	CA Undetermined effect	Executive compensation +
Explanatory Var. #2Effet expected		Net income +	Age of the company -	Claims +	Executive compensation +	
Explanatory Var. #3Effet expected		*[7]	Age of manager -	ROA +		

[7] By highlighting in bright red those that have been confirmed by statistical analysis.

Authors	Gèraudel M. and Chollet B. (2009)	Ndangwa L., Sonna F. and Djeumene P. (2007)	Collins C. and Clark K. (2003)	Vigliano M. and Barré G. (2010)
Country of analysis	Canada	Cameroon	United States	France
Explanatory Var. #4Effet expected			ROE +	

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Data availability Not applicable.

Declarations

Ethical Approval Not applicable as this study did not involve human or animal participants. Therefore, no ethical committees, internal review boards, or specific guidelines were followed.

Competing interests The author declares no competing interests, whether financial or personal, that could have influenced the outcome or interpretation of this research.

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