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Analysing Drivers of Knowledge Leakage in Collaborative Agreements: A Magnetic Processing Case Firm

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Abstract: Due to the embeddedness of organisations in networks, collaborations, and business relationships, knowledge leakage has become a common concern. In this regard, this paper aims to investigate drivers of knowledge leakage in collaborative agreements using an integrated ISM-MICMAC model. Based on insights from employees including the CEO of a magnetic processing firm, we validate the proposed model. The findings of our study reveal nine key drivers that influence knowledge leakage in collaborative agreements. In terms of level of influence, incomplete contract is the most influential driver, followed by sub-contracting activities. Last, the nine drivers are classified into two main clusters: independency cluster—weak dependence power with high driving power—and linkage cluster—strong dependence and driving power.

Keywords: knowledge leakage; interpretive structural model (ISM); MICMAC analysis; collaborative agreements; driver; case study; small firm

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1. Introduction

The uncertain business landscape, where continuous updating of knowledge is essential for securing a sustained competitive advantage (Durst 2020; Yang et al. 2021), underscores the importance of collaboration among organisations even more. By establishing a collaborative agreement—which is essentially an agreement between organisations to work together to achieve a mutually beneficial objective—organisations can align their resources to create new knowledge and remain competitive (Papadas et al. 2019; Pateman et al. 2016; Zhou et al. 2022). Collaboration among organisation is indisputable as a crucial ingredient to successfully realising projects (Bond-Barnard et al. 2018), particularly when each partner possesses complementary resources that are rare and unique (Belderbos et al. 2015). It has been shown that when organisations collaborate, projects can be accomplished more effectively and efficiently because they are able to overcome individual limitations in ability and resources that would otherwise impede the execution or completion of projects.

Despite the fact that collaborations have many advantages, there is also a dark side. A possible dark side to collaboration arises from the exchange of information or knowledge, the very basis of collaboration (Garousi Mokhtarzadeh et al. 2021; Scaliza et al. 2022). It is this bidirectional flow of knowledge that can cause valuable organisational knowledge to seep out with the wrong persons. This phenomenon is often referred to as "knowledge leakage". As defined by Frishammar et al. (2015), knowledge leakage is the disclosure of valuable knowledge that is supposed to remain within the boundaries of an organisation. In the context of collaboration, knowledge leakage can also result from firms misappropriating valuable knowledge of a focal firm in an inter-organisational framework. Typically, this happens when partners develop opportunistic behaviour in pursuit of self-interest and are less willing to cooperate (Jiang et al. 2013).

Although it is evident from the literature on collaborations that knowledge sharing and knowledge creation have received considerably more attention (e.g., Goi et al. 2022; Ho and Ganesan 2013; Kleber et al. 2019), research on knowledge leakage, in general, is relatively growing (Durst et al. 2015). Previous studies (e.g., Ahlfänger et al. 2022; Fawad Sharif et al. 2022; Jiang et al. 2016; Oxley and Sampson 2004; Raza-Ullah 2021) on knowledge leakage in collaboration (be it, e.g., strategic alliances or coopetition) have largely focused on governance control mechanisms, such as formal and informal contracts (i.e., social contract based on trust). These mechanisms have been used primarily for controlling and minimising knowledge leakage in different forms of collaboration. As an example, Fawad Sharif et al. (2022) analyse how distrust, partner learning intent, and human resource management influence knowledge leakage in collaborative projects. In a strategic alliance, Jiang et al. (2016) examine the links between partners' trustworthiness and knowledge leakage. Besides the fact that knowledge leakage is not a fully understood phenomenon yet, previous research has provided limited insights into the factors that may cause knowledge leakage in collaborative settings (Li and Kang 2019). Consequently, there is little evidence of identifying and modelling the interactions between the drivers of knowledge leakage, particularly in collaborative settings. This gap in the literature is worth addressing for important reasons. First and foremost, to have a better understanding of this fragmented research field (Durst et al. 2015). A second consideration is that, since it appears that knowledge leakage is intrinsically a complex phenomenon (Durst et al. 2015; Wu et al. 2021), a deeper understanding of knowledge leakage within the context of collaborative agreements, as a complex social system, can also be developed. In specific terms, addressing this gap is imperative, as it would provide a clearer picture of this complexity issue that is often only hinted at (Wang et al. 2021; Wayne Gould 2012; Wu et al. 2021) which in turn is important for the further development of knowledge leakage as an important element of both (knowledge) risk management and knowledge management in general (Zieba et al. 2022).

Therefore, this study proposes an integrated interpretive structural modelling (ISM)—Cross-Impact Matrix Multiplication Applied to Classification (MICMAC) model to investigate drivers of knowledge leakage in collaborative agreements and establish their interrelationships. Specifically, the research objectives are as follows:

- To identify key drivers of knowledge leakage in collaborative agreements;
- To establish hierarchical relationships among the drivers;
- To classify the drivers based on their driving and dependency power; and
- To validate the model using a magnetic processing firm as a case study.

The following justifies the selection of a magnetic processing firm as the subject of the case study. The firm is a small and privately-owned enterprise that specialises in magnetic processing, using high-tech to develop non-assembled and highly customised products for its clients. The industry is competitive, as acknowledged by an employee from the case firm, it also forms part of a global supply chain network, positioning the firm in a more complex environment. This poses a greater threat regarding knowledge leakage (Durst and Ferenhof 2014; Durst et al. 2015; Oxley and Wada 2009). Additionally, due to its small size, the firm faces the problem of liability of smallness, making it heavily dependent on its partners, suppliers and clients, which increases the possibility of knowledge leakage thus making the selected firm an appropriate study subject.

The first research objective is achieved by conducting a thorough literature review, based on peer-reviewed scientific papers, and further validated by the opinions of employees from the case firm. The second research objective is achieved by using the ISM technique, which is widely used to establish interrelationships between complex variables (Ali et al. 2022; Singh et al. 2019). The third objective of the research is addressed using MICMAC analysis. MICMAC has been deemed an effective analysis tool for classifying variables into distinct clusters with unique characteristics (Jung et al. 2021). Finally, the fourth objective is reached through the continued involvement of the employees including the CEO of the case firm.

To this end, this research contributes in several ways to advance the study of knowledge leakage by focusing on the interrelationships between key drivers of knowledge leakage in collaborative agreements. First, a comprehensive overview and description of drivers that have been reported in the literature are provided. Furthermore, this study incorporates the employees'—from the case firm—inputs to build an integrated model using the ISM technique and MICMAC analysis, a first in knowledge leakage studies. Finally, this work supports practitioners in developing a better understanding of the complex nature of knowledge leakage in collaborative settings.

The remainder of this paper is structured as follows: Section 2 presents a literature review. Section 3 provides an overview of the research methodology. The Section 4 presents the model development and validation while Section 5 discusses the final model and its implications. Finally, Section 6 concludes with some limitations and suggested future research directions.

2. Literature Review

2.1. Knowledge Leakage in Collaborative Agreements

According to several studies (e.g., Durst and Ferenhof 2014; Guo et al. 2021; Zhao and Liang 2011), collaborative agreements can expose organisations to the danger of knowledge leakage. In collaborative agreements that are based on co-opetition, where collaboration and competition are intertwined (Hoffmann et al. 2018), the likelihood of knowledge leakage becomes even more evident. Theoretically, collaborative agreements are designed to bring organisations together to accomplish a shared objective by learning from one another and more efficient use of resources (Bakker et al. 2008), however, this may not necessarily be the case in practice, since partners may have incongruent private interests, resulting in opportunistic behaviour such as misappropriation of knowledge (Jiang et al. 2013). Although the exchange of knowledge between firms is necessary, the more core knowledge is shared, the greater the likelihood of losing the firm's competitive advantage (Frishammar et al. 2015; Galati et al. 2019). In this regard, it is necessary to find and maintain a balance.

Kaiser et al. (2021) expressed a similar viewpoint regarding the optimal level of knowledge sharing and knowledge protection practices as a means of minimising knowledge leakage. Using a semiconductor industry context, they designed a grey-box model to protect knowledge from leakage in data-centric collaborations. Kunttu and Neuvo (2019) found that mutual trust building, based on a personal level relationship, is one of the key processes that enable partners to balance learning and protection while simultaneously lowering informational barriers in collaborations. In an R&D collaborative project, Hurmelinna-Laukkanen (2011) examined 242 Finnish companies in order to better understand the issue of maintaining an optimal balance between knowledge sharing and knowledge protection primarily to curb knowledge leakage. Their results revealed that the efficient application of knowledge protection while engaging in knowledge sharing practices among varying partners facilitates innovation performance. This confirms the existing notion of an appropriate balance between knowledge sharing and knowledge protection.

To illuminate the dilemma of knowledge protection and knowledge sharing in collaborative business partnerships, Wei et al. (2018) drew upon transaction cost and psychological contract theories. The authors were primarily interested in determining how knowledge protection affects partnership quality and project outcomes. Results showed that knowledge protection adversely impacted partnership quality and project performance. Likewise, this demonstrates the importance of having a balanced approach to knowledge sharing to maximise project performance and knowledge protection to minimise knowledge leakage. The determination of the right equilibrium justifies the complexity associated with knowledge leakage in collaborative arrangements.

2.2. Key Drivers of Knowledge Leakage in Collaborative Agreements

Having reviewed the literature, we identified several drivers of knowledge leakage in collaborative agreements. Opportunistic behaviour has been identified as one driver that may trigger knowledge leakage in collaborations among firms (Estrada et al. 2016; Fawad Sharif et al. 2020b). As early as 1975, Williamson (1975) defined opportunistic behaviour as “self-interest seeking with guile” (p. 9). In collaborative agreements, opportunistic behaviour is accompanied by a breach of trust as a partner attempts to misappropriate proprietary knowledge (Estrada et al. 2016; Jiang et al. 2013).

Distrust is regarded as one of the most critical drivers of knowledge leakage in collaborative agreements (Raza-Ullah 2021); which is defined as the expectation that a partner will act detrimentally to the focal firm (Govier 1994). According to Fawad Sharif et al. (2022), the lack of trust is responsible for knowledge leakage since the presence of distrust leads partner firms to focus on personal goals instead of the project’s overall objectives. This, in turn, can result in them developing opportunistic intentions and misappropriating valuable knowledge from the focal firm. One way to restrain opportunistic actions is through the implementation of a formal contract between collaborating firms which is in line with the transaction cost theory. In contrast, “without formal contracts, partner firms have stronger incentives to acquire each other’s knowledge beyond the scope of the cooperative agreement” (Jiang et al. 2013, p. 985). Thus, the lack of formal contracts may allow opportunistic behaviour to spread between partner firms, resulting in knowledge leakage.

An era in which inter-firm collaborations are increasingly driven by digital transformation (Appio et al. 2021), inadequate technological competence of employees (Altukruni et al. 2021), weak Bring-Your-Own-Device (BYOD) policies (Serna et al. 2017), and substandard security measures (Altukruni et al. 2021; Durst and Zieba 2019) pose a risk of sensitive knowledge being exposed or compromised. This exposed knowledge may even end up with external parties who are not part of the collaborative agreement and eventually result in reputational damage (Ahmad et al. 2014) and loss of competitiveness for the affected firm (Durst et al. 2015; Ritala et al. 2015).

Moreover, research (e.g., Nishat Faisal et al. 2007; Norman 2002; Oxley and Wada 2009) has strongly linked knowledge leakage to subcontracting activities such as outsourcing, which are typically referred to as vertical relationships (Tidd and Izumimoto 2002). According to some scholars (e.g., Belderbos et al. 2004; Huo et al. 2022), vertical relationships orchestrate knowledge leakage less since they are mostly non-competitive. However, this may not always be the case since downstream partners may wish to take advantage of the upstream firm’s dependence (Fang et al. 2016).

Individual incentives may also trigger knowledge leakage in collaborative agreements, but research on this aspect has been scarce (Tan et al. 2016). In this case, an employee is incentivised to provide confidential information about his/her firm to outsiders through fraudulent means, resulting in inappropriate knowledge disclosure. In this regard, dissatisfied or disloyal employees—viewed as a concrete form of knowledge leakage (Durst and Ferenhof 2014)—may be a target for engaging in such activities. In addition, collaboration between competing firms may lead to knowledge leakage (Lee 2002; Zhao et al. 2002). It is the tension between value creation and value appropriation that often causes partners to act opportunistically, which increases the likelihood of knowledge leakage (Raza-Ullah and Eriksson 2017). The situation is even more precarious in that competing firms often possess specialised knowledge that gives them an edge over their competitors, so when knowledge leaks occur, there can be significant adverse effects on the firm in question.

Below (Table 1) is a summary of the identified drivers of knowledge leakage in collaborative agreements pending opinions from employees of the case firm for validation.

Table 1. Literature support to the identified drivers.

Codes	Drivers	Descriptions	References
D01	Distrust	Neither of the partners involved in collaborative agreements can be relied upon by the other.	Qiu and Haugland (2019), Jiang et al. (2016), Yang et al. (2019), Taylor (2005), Guo et al. (2020), Deniaud et al. (2016), Fawad Sharif et al. (2020b, 2022), and Vafaei-Zadeh et al. (2020)
D02	Incomplete contracts	Weak or no legal contract in place to protect the core knowledge of partners involved in the collaboration.	Jiang et al. (2013), Yang et al. (2019), Taylor (2005), Guo et al. (2020), Ahlfänger et al. (2022), Deniaud et al. (2016), and Fawad Sharif et al. (2020b)
D03	Substandard security measures	Lack or inadequate security guidelines to oversee knowledge exchange between partners in collaborative arrangements.	Hislop et al. (2018), Durst and Zieba (2019), Frishammar et al. (2015), and Altukruni et al. (2021)
D04	Weak BYOD policies	A lack of strict rules underpinning bring your own device (BYOD) policies could expose the focal and partner firms' core knowledge to cyberattacks (third party).	Serna et al. (2017), Shabtai et al. (2012), and Altukruni et al. (2021)
D05	Insufficient technological competence	Emerging technologies used in collaborative arrangements put a firm's core knowledge at risk of leakage due to a lack of tech know-how.	Ahmad et al. (2014), Hislop et al. (2018), Jiang et al. (2013), Christina et al. (2016), Altukruni et al. (2021), and Zeiringer and Thalmann (2022)
D06	Perceived opportunism	Partners attempt to gain an advantage by misappropriating the core knowledge of the focal firm.	Estrada et al. (2016), Norman (2002), Oxley and Wada (2009), and Fawad Sharif et al. (2020a, 2022)
D07	Expected incentives	The act of exposing core knowledge to a partner or external party for an incentive by a player in collaborative arrangements.	Tan et al. (2016)
D08	Existence of horizontal competition	Cooperation encourages partners to take advantage of exposed core knowledge.	Lee (2002), and Zhao et al. (2002)
D09	Sub-contracting activities	Cooperation agreements between firms often result in subcontracting activities rather than collaborations, which often result in unknowingly transferred core knowledge.	Tan et al. (2016), Foli (2022), Nishat Faisal et al. (2007), Dye and Sridhar (2003), and Zhang et al. (2011)

3. Research Methodology

The research methodology, which integrated the ISM technique and MICMAC to analyse key drivers of knowledge leakage in collaborative agreements, used for this study is illustrated in Figure 1. In this integrated model, the ISM technique is used to establish a contextual relationship among the drivers and leads to the development of a structural model of the drivers, while the MICMAC analysis is used to categorise the drivers into clusters based on their influencing power.

Several multi-criteria decision-making (MCDM) techniques are available in the literature, which are considered effective at addressing complex issues, such as DEMATEL, Graph theory, AHP, and ANP (dos Santos Gonçalves and Campos 2022). In DEMATEL, for example, cause-effect relationships between variables are revealed. Graph theory can be used to establish interactions among variables; however, the graph edges pose a reliability concern (Wagner and Neshat 2010). In terms of drawing a hierarchy of variables, AHP is an effective tool (Jakhar and Barua 2014). The ANP can also provide dependencies between variables, but it is considered complicated and not widely accepted (Zhao et al. 2021).

None of the MCDM techniques is effective in establishing contextual relationships between variables by assessing their influencing power, as ISM-MICMAC does (Bux et al. 2020).

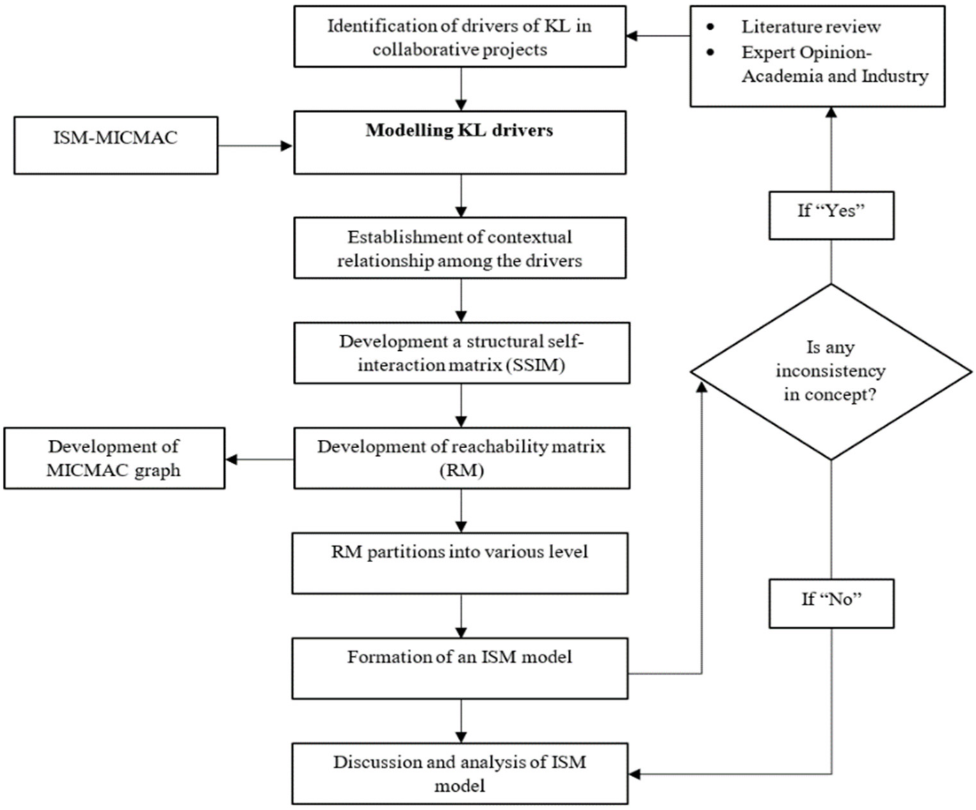

Figure 1. Steps in the research methodology.

Researchers have utilised the ISM-MICMAC integrated approach in a wide variety of areas, such as promoting sustainability through corporate social responsibility (Bux et al. 2020), managing risks in the agri-food supply chain (Ramos et al. 2021), addressing barriers to Industry 4.0 (Goel et al. 2022) and reducing supply chain risks in wind power projects (Troche-Escobar et al. 2018).

As a starting point, the key drivers of knowledge leakage in collaborative agreements identified through the literature review were listed in an Excel spreadsheet along with brief descriptions, which were then sent via email in advance to the case firm. Having access to this firm was made possible through an employee of the firm who participated in a summer school in connection with a research project. This employee mainly serves as the firm's communication officer with additional responsibilities such as risk management and ESG strategy implementation and is the direct point of contact with the firm's collaborators, i.e., suppliers, partners, and B-to-B customers; whose role is suitable for the present study.

In the validation process, two discussion sessions were conducted following Haleem et al.'s (2016) work. During the first discussion session, the communication officer, the CEO, and two members of the operations team participated. This discussion aimed to validate the identified drivers derived from the literature, which is the immediate step prior to the modelling phase. Additionally, this met the minimum eligibility criteria for the use of this technique (see Haleem et al. 2016; Mathiyazhagan et al. 2013; Ravi and Shankar 2005). While in the second session, discussions were held in order to reach a consensus concerning the contextual relationships among the validated drivers; a phase technically included in the modelling process.

The next sections discuss the modelling phase of the validated drivers.

3.1. Interpretive Structural Modelling (ISM) Technique

Managing knowledge leakage in collaborative arrangements is a demanding task, particularly since it involves drivers that are complex in nature. Due to this reason, a powerful tool is necessary to assist in understanding and managing this complexity. ISM meets this requirement. Warfield (1973) developed the ISM to examine complex issues by analysing unorganised factors and converting them into a well-structured model. The interpretive nature of this technique derives from its ability to utilise experts in its application. By applying this technique, it is possible to establish interrelationships among the identified drivers of knowledge leakage in collaborative agreements and construct a structured model based on the knowledge and experience of the case firm's employees.

Following the first step which identified and validated the key drivers, the ISM technique was applied as follows:

- Contextual relationship between the identified key drivers is developed to determine which pairs of drivers should be checked;
- Structural self-interaction matrix (SSIM) is developed for the drivers that show pairwise relationships among them;
- Reachability matrix (RM) is derived from the SSIM by replacing each cell entry with 1 and 0, as well as checking the matrix for transitivity. Assuming transitivity of contextual relations is a fundamental tenet of ISM. The rule states that if *variable A* is related to *variable B* and *variable B* is related to *variable C*, then *variable A* is necessarily related to *variable C*. This leads to the development of a final RM;
- Final RM is partitioned into several levels;
- ISM model is developed based on the contextual relationships given above and then transitive links are removed;
- Developed ISM model is reviewed to ensure that any conceptual inconsistencies and necessary modifications are considered.

3.2. Cross-Impact Matrix Multiplication Applied to Classification (MICMAC) Analysis

Duperrin and Godet (1973) proposed MICMAC analysis for assessing indirect relationships among system elements. Among managers, it is also considered useful for in-depth analysis of a system (Elmsalmi and Hachicha 2013). In this study, we used the MICMAC analysis to classify the identified key drivers of knowledge leakage in collaborative agreements according to their driving power (DrP) and dependence power (DeP). According to Figure 1, the MICMAC graph is derived from the final RM, by summing across the rows and columns of the final RM to determine each driver's driving power and dependence power. The drivers were then classified into four clusters (Wu et al. 2022):

Autonomous drivers (Cluster I) possess weak driving and dependence powers. These drivers are often referred to as excluded drivers due to their limited influence.

Dependent drivers (Cluster II) possess weak driving power but strong dependence power. For decision makers, these drivers represent an unfavourable outcome.

Linkage drivers (Cluster III) possess strong driving and dependence powers. Typically, these drivers are unstable.

Independent drivers (Cluster IV) possess strong driving power but weak dependence power. They are generally considered to be the most important drivers and are accorded the highest priority.

4. Model Development and Validation

Based on the research methodology presented earlier, we developed an integrated ISM-MICMAC model, which was validated through a case firm. To maintain the firm's anonymity, we used Alpha as a pseudonym. Alpha is a leader in the magnet technology market based in Germany. It provides sophisticated and customised magnetic products to its clients, making it a firm with a high level of expertise. As Alpha's production of magnetic products is dependent upon raw materials imported from outside Europe, it belongs to a global supply chain network. For this reason, Alpha engages in a wide variety of collaborative agreements. As a result, there is a high risk of knowledge leakage, especially when dealing with their partners and business-to-business clients. As mentioned previously, due to Alpha's knowledge-intensive nature and external collaborations, it was viewed as an appropriate case firm to validate a model regarding knowledge leakage.

4.1. Application of Integrated ISM-MICMAC Model

4.1.1. Structural Self-Interaction Matrix (SSIM)

Following the identification of the nine drivers that influence knowledge leakage in collaborative agreements through the literature review and their validation based upon opinions obtained from employees of the case firm, in the next step contextual relationships were determined. The contextual relationship is one of the steps in the ISM modelling that heavily relies on the inputs from the involved participants (Foli 2022; Ramos et al. 2021). Through multiple discussions and reflections, the employees were able to establish relationships among the nine drivers identified. As a guideline, we adopted the following four conventional symbols as widely used in the literature (e.g., Sushil 2012) to assign relationships among the drivers:

- V for a forward relation of *driver* i to j (*driver* i will influence *driver* $j/i \rightarrow j$);
- A for backward relation of *driver* i to j (*driver* j will influence *driver* $i/j \rightarrow i$);
- X for a bidirectional relation of *drivers* i and j (*drivers* i and j will influence each other $/i \longleftrightarrow i$); and
- O for no relation exists between *drivers* i and j (*drivers* i and j have no influence on each other).

Based on contextual relationships, the SSIM is derived by using the symbols as cell entries as shown in Table 2.

Table 2. Structural self-interaction matrix (SSIM).

Drivers	D01	D02	D03	D04	D05	D06	D07	D08	D09
D01		A	O	O	O	X	A	X	O
D02			O	O	O	V	V	V	V
D03				V	V	X	X	V	O
D04					X	V	O	O	O
D05						V	X	V	A
D06							X	A	A
D07								X	A
D08									X
D09									

4.1.2. Reachability Matrix (RM)

As a next step, the SSIM derived in the previous section was transformed into an initial reachability matrix. To do this, we converted each cell entry in the SSIM into binary, i.e., 0's and 1's, where zero represents no interrelationship between the drivers, whereas one indicates there is an interrelationship between them. Since these cell entries are symbols, we transformed them according to the following rules (Bux et al. 2020; Foli 2022):

- For SSIM cell entries (i, j) denoted by V, the initial reachability matrix cell entries (i, j) become 1 and (j, i) become 0;
- For SSIM cell entries (i, j) denoted by A, the initial reachability matrix cell entries (i, j) become 0 and (j, i) become 1;
- For SSIM cell entries (i, j) denoted by X, the initial reachability matrix cell entries (i, j) and (j, i) become 1; and
- For SSIM cell entries (i, j) denoted by O, the initial reachability matrix cell entries (i, j) and (j, i) become 0.

Upon application of the rules, the initial reachability matrix was determined as shown in Table 3. The initial reachability matrix is then used to determine the final reachability matrix. The final reachability matrix (see Table 4) is constructed based on the transitivity rule, which states that if *driver i* influences *driver j* and *driver j* influences *driver k*, then *driver i* has an influence on *driver k*.

Table 3. Initial reachability matrix.

Drivers	D01	D02	D03	D04	D05	D06	D07	D08	D09
D01	1	0	0	0	0	1	0	1	0
D02	1	1	0	0	0	1	1	1	1
D03	0	0	1	1	1	1	1	1	0
D04	0	0	0	1	1	1	0	0	0
D05	0	0	0	1	1	1	1	1	0
D06	1	0	1	0	0	1	1	0	0
D07	1	0	1	0	1	1	1	1	0
D08	1	0	0	0	0	1	1	1	0
D09	0	0	0	0	1	1	1	0	1

Table 4. Final reachability matrix.

Drivers	D01	D02	D03	D04	D05	D06	D07	D08	D09	DrP
D01	1	0	1 *	1 *	1 *	1	1 *	1	0	7
D02	1	1	1 *	1 *	1 *	1	1	1	1	9
D03	1 *	0	1	1	1	1	1	1	0	7
D04	1 *	0	1 *	1	1	1	1 *	1 *	0	7
D05	1 *	0	1 *	1	1	1	1	1	0	7
D06	1	0	1	1 *	1 *	1	1	1 *	0	7
D07	1	0	1	1 *	1	1	1	1	0	7
D08	1	0	1 *	1 *	1 *	1	1	1	0	7
D09	1 *	0	1 *	1 *	1	1	1	1 *	1	8
DeP	9	1	9	9	9	9	9	9	2	

* denotes transitivity relationship.

4.1.3. Level Partitions

In this step, the final reachability matrix was systematically partitioned into different levels, using the sets of reachability, antecedents, and intersections from the final reachability matrix. A reachability set (Rsi) was obtained for each driver across the final reachability matrix in the horizontal direction with cell entries “1”. The antecedent set (Asi) was similarly derived for each driver across the final reachability matrix in the vertical direction with cell entries “1”. As for the intersection set, it was derived through an iterative partitioning process. For example, as shown in Table 5, drivers D01, D03, D04, D05, D06, D07, and D08 are assigned to Level 1 since their Rsi intersected with their Asi exhaustively, while the rest did not. This process was repeated until all the drivers had been partitioned.

4.1.4. Formation of ISM Model

The ISM model of the drivers was derived from the final reachability matrix. It is important to note that the final reachability matrix includes transitivity relationships; these transitivity relationships were removed in order to maintain only direct interrelationships. As demonstrated in Figure 2, the interrelationships between drivers are indicated by arrows. In the case of D08 and D01, for example, there are two arrows at the end, which indicates that D01 exerts a direct influence on D08 and vice versa.

Table 5. Level partition for the drivers.

D0′s	Reachability Set (Rsi)	Antecedent Set (Asi)	Intersection Set (Isi)	Level
Iteration 1				
D01	1,3,4,5,6,7,8	1,2,3,4,5,6,7,8,9	1,3,4,5,6,7,8	I
D02	1,2,3,4,5,6,7,8,9	2	2	
D03	1,3,4,5,6,7,8	1,2,3,4,5,6,7,8,9	1,3,4,5,6,7,8	I
D04	1,3,4,5,6,7,8	1,2,3,4,5,6,7,8,9	1,3,4,5,6,7,8	I
D05	1,3,4,5,6,7,8	1,2,3,4,5,6,7,8,9	1,3,4,5,6,7,8	I
D06	1,3,4,5,6,7,8	1,2,3,4,5,6,7,8,9	1,3,4,5,6,7,8	I
D07	1,3,4,5,6,7,8	1,2,3,4,5,6,7,8,9	1,3,4,5,6,7,8	I
D08	1,3,4,5,6,7,8	1,2,3,4,5,6,7,8,9	1,3,4,5,6,7,8	I
D09	1,3,4,5,6,7,8,9	2,9	9	
Iteration 2				
D02	2,9	2	2	
D09	9	2,9	9	II
Iteration 3				
D02	2	2	2	III

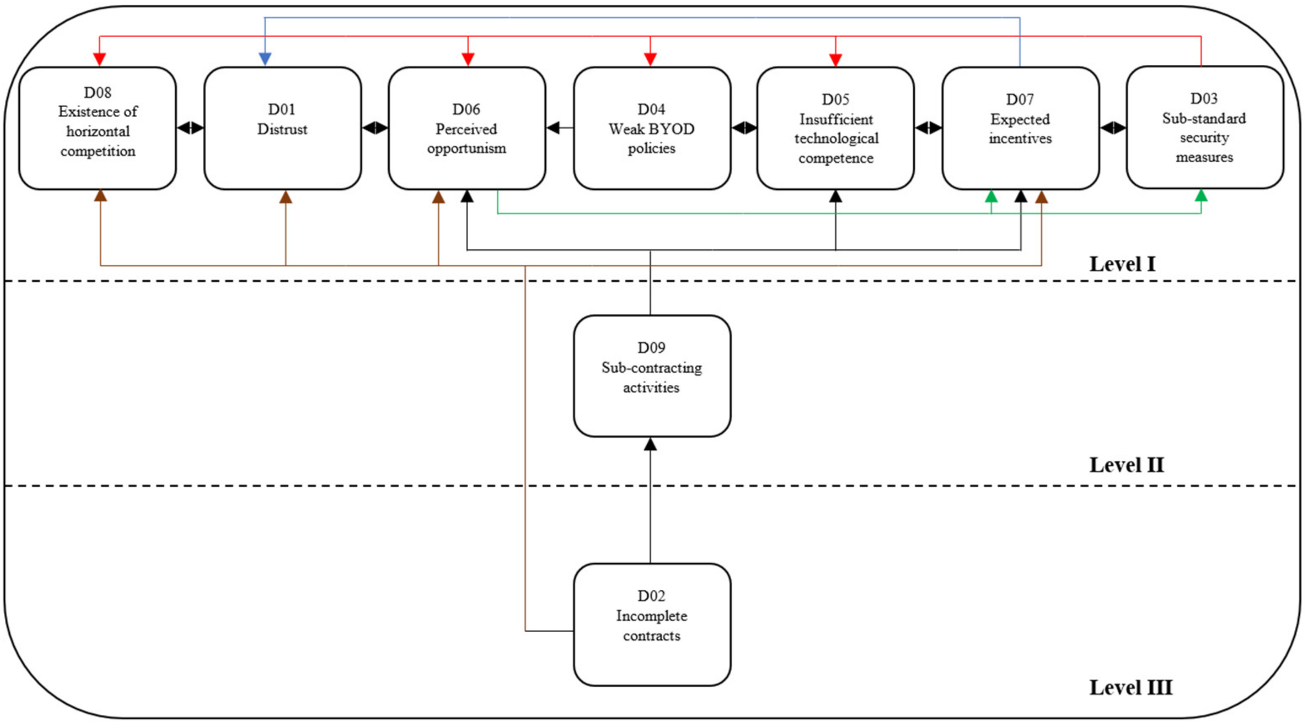

Figure 2. ISM model.

Moreover, the ISM provides a detailed representation of the drivers based on their level partitions. In the model, D01, D03, D04, D05, D06, D07, and D08 were structurally placed at the top, followed by D02 and D09.

4.1.5. MICMAC Analysis

Finally, we used the MICMAC analysis to classify the drivers into clusters. The result of the analysis generated two clusters—the *Independent* cluster and the *Linkage* cluster (Figure 3). No driver was placed under the *Autonomous* or the *Dependent* cluster.

Considering that D02 and D09 have a high driving power, but a low dependent power, they were assigned to the *Independent* cluster. Whereas D01, D03, D04, D05, D06, D07, and

D08 were classified under the *Linkage* cluster since they possess a high degree of driving and dependence.

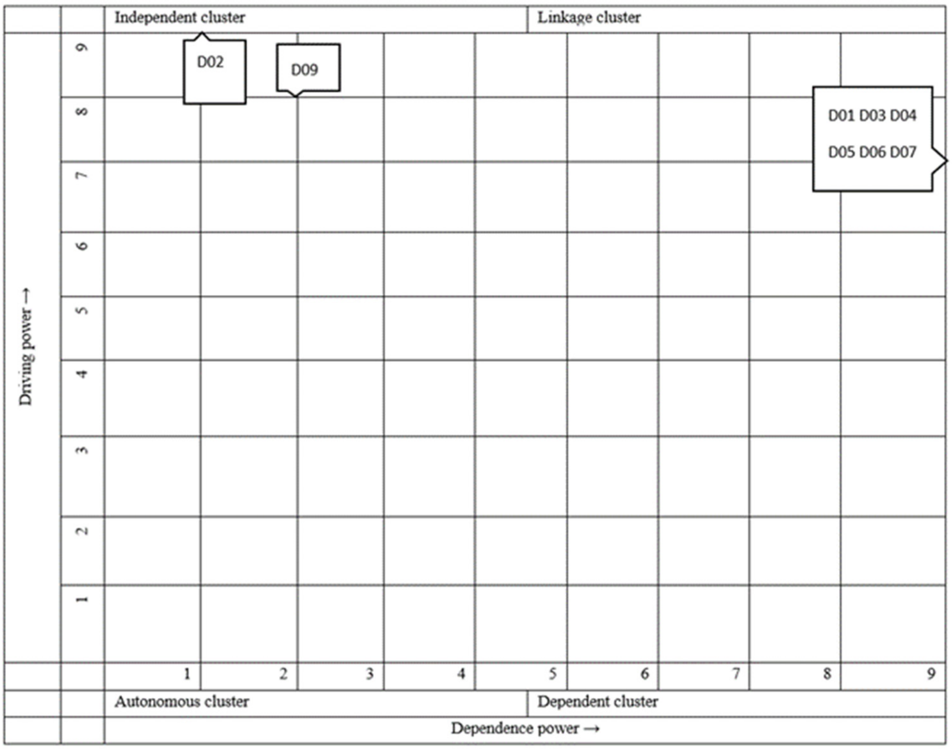

Figure 3. MICMAC analysis.

5. Discussion

Our research revealed nine key drivers of knowledge leakage in collaborative agreements. Besides the relevance of the identified drivers in the literature, employees including the CEO of the case firm confirmed their practicality at the collaborative level. Consequently, our findings regarding the drivers of knowledge leakage in collaborative agreements are in line with those found in the literature. As an example, distrust as a driver of knowledge leakage is consistent with studies from Fawad Sharif et al. (2020b, 2022) which found that distrust significantly influenced knowledge leakage in collaborative projects. Our findings also support previous studies (e.g., Jiang et al. 2013) that found incomplete contracts to be associated with knowledge leakage in similar collaborative settings. The validation of substandard security measures, weak BYOD policies, insufficient technological competence, perceived opportunism, expected incentives, the existence of horizontal competition, and sub-contracting activities as contributing factors to knowledge leakage is consistent with various findings in the literature (e.g., Serna et al. 2017; Zeiringer and Thalmann 2022).

The results of the ISM model indicate that there are three partitions among the nine identified drivers, which are hierarchical in nature and have several interdependencies. It is clear from this that knowledge leakage is a complex issue (Kaiser et al. 2021) and therefore requires a more holistic approach (Durst and Zieba 2019). Further, we observe that an incomplete contract in collaborative agreements contributes significantly to knowledge leakage, as it forms the foundation of the ISM hierarchy. Considering the fact that most previous studies (e.g., Jiang et al. 2013; Fawad Sharif et al. 2020b) have reached similar conclusions, this is not surprising. Additionally, the ISM model indicates that incomplete contracts are associated with perceived opportunism. The reason for this can be explained in the context of a given collaborative project in which the contractual binding involving firms is not comprehensive. This paves the way for opportunistic behaviour to prevail and thrive, resulting in knowledge leakage. It is also found that an incomplete contract is directly linked to distrust. In a similar vein, when partners demonstrate a lack of commitment in a collaborative agreement, it is likely to result in distrust among them. Likewise, Fawad Sharif et al. (2020b) conclude that the existence of more complete contract can lead to higher levels of trust. It is clear from the above that contract design has an important role to play in minimising knowledge leakage (knowledge protection), confirming previous research. It also underlines the need for understanding the link between trust and formal contracts with regard to knowledge leakage (Jiang et al. 2013).

Despite the benefits of subcontracting, such as reduced costs, improved service quality, and more time to focus on the core business, it is also considered to be a significant driver of knowledge leakage in collaborative agreements. As shown in the ISM model, subcontracting activities have a direct correlation with perceived opportunism, insufficient technological competence, and expected incentives. As tasks are outsourced outside of a project, external collaboration is necessary, either in the form of sharing insight and knowledge about the project with subcontractors or third parties. In turn, such external collaboration can result in vertical relationships (Nishat Faisal et al. 2007) that breed opportunistic behaviour among partners. In relation to the correlation between subcontracting activities and insufficient technological competence, Durst and Zieba (2019) argue that the more firms outsource, the more they tend to rely on their contractors, consequently losing the necessary skills and capacities to operate the business. These skills could be technical capabilities to protect key organisational assets such as knowledge.

The upper hierarchy of the ISM model consists of the existence of horizontal competition, distrust, perceived opportunism, weak BYOD policies, insufficient technological competence, expected incentives, and substandard security measures. Among the drivers, substandard security measure is the most interconnected. It is directly associated with horizontal competition, perceived opportunism, weak BYOD policies, insufficient technological competence, and expected incentives. Thus, it implies that, without measures like security, many drivers may emerge and contribute to knowledge leakage (Altukruni et al. 2021). As well, it is important to note that even though substandard security measure has numerous connections, it is less influential due to their lower driving power when compared to subcontracting activities and incomplete contracts.

Finally, the MICMAC findings indicate that the nine key drivers of knowledge leakage in collaborative agreements can be classified into two main clusters. Based on the results, incomplete contracts and sub-contracting activities are placed under the *Independent* cluster. This indicates that incomplete contracts and subcontracting activities have a strong driving force, but a weak dependence power. This confirms their position at the bottom of the ISM hierarchy. A well-written contract, according to Qiu and Haugland (2019), specifies each company's rights and responsibilities, along with the primary motive of the collaboration. In this regard, if a contract such as this is not available, it may lead to undesirable behaviours and traits, such as opportunism (Fawad Sharif et al. 2020a) and distrust (Fawad Sharif et al. 2022; Yang et al. 2019). It is therefore understandable why incomplete contracts attained the highest driving power as far as knowledge leakage in collaborative agreements is concerned. The remaining drivers, which include the existence of horizontal competition, distrust, perceived opportunism, insufficient technological expertise, expected incentives, and substandard security measures, are included in the *Linkage* cluster, which implies that they possess strong driving and dependence powers. Based on our findings, it appears that the drivers in the *Linkage* cluster have a relatively lower driving power than those in the *Independent* cluster, as this explains why the seven drivers in the *Linkage* cluster are placed at the top of the ISM hierarchy.

Implications

This study specifically contributes to the knowledge leakage research field by establishing interrelationships among drivers of knowledge leakage in collaborative agreements, in contrast to previous studies that have primarily focused on mediation-moderation relationships. This was achieved by first proposing an integrated ISM-MICMAC model and then by validating the model using a single case. Therefore, it can be argued that this study is one of those first attempts to integrate the ISM technique and MICMAC analysis to analyse knowledge leakage drivers. Further, the authors have attempted to answer calls for robust approaches in understanding the phenomenon of knowledge leakage by using a modelling research design approach (e.g., Li and Li 2021; Wu et al. 2021).

For practitioners, the study offers decision makers such as CEOs, managers, and directors a better understanding of the complexity of knowledge leakage when engaging in collaborative projects. Additionally, the findings provide risk managers in smaller businesses in particular with a list of key drivers of knowledge leakage that have been validated based upon opinions obtained from employees of the case firm in likely similar industries. It is also possible that these findings may be useful and relevant to risk managers working in other contexts. Moreover, it seems beneficial for project managers involved in collaborative projects to develop strategies for successfully implementing projects in response to the identified driver to minimise knowledge leakage concerns. In addition, the proposed integrated ISM-MICMAC model would also serve as a useful tool for managers to support their existing risk management frameworks.

6. Conclusions

In this study, drivers of knowledge leakage in collaborative agreements were analysed using an integrated ISM-MICMAC model validated by employees including the CEO of a magnetic processing firm located in Germany. Based on a literature review and supported by inputs obtained from employees of the case firm, nine key drivers were identified and validated. Through the application of the ISM-MICMAC model, hierarchical interrelationships and classification of the drivers were achieved. While the ISM technique was helpful in establishing interrelationships, the MICMAC analysis assisted in classifying them according to their driving and dependence powers.

Hence, the major contribution of this study to theory is the development of the integrated ISM-MICMAC model, by fulfilling the proposed objectives. As a result, the study has attempted to answer the "what", "how", and "why" questions, which are fundamental to theory building (Whetten 1989). The "what" question has been answered by identifying drivers of knowledge leakage from the literature and validated based upon opinions obtained from employees of the case firm. By demonstrating the strength and power of these drivers through interpretive analysis, the "how" and "why" questions have also been addressed.

Limitation and Future Research Directions

Since the ISM-MICMAC model is based on a single firm (i.e., the small magnetic processing firm), it may be biased and limited in its application to one industry. It is therefore recommended that future research consider different contexts, including various types of industries and SMEs, in order to strengthen the generalisability of the findings. As nine drivers were identified for the development and validation of the model, future work may consider exploring additional drivers. From our findings, we discovered a few relationships among the drivers that we could not compare and contrast with literature since there were no studies regarding their nature; therefore, we may use system dynamics modelling (SDM) or statistical methods such as structural equation modelling (SEM) to verify these relationships in future studies. Finally, it may be worthwhile to employ longitudinal studies in the future to investigate the phenomenon of knowledge leakage over time, given its complexity.

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