EVALUATING THE SUPPLY CHAIN MANAGEMENT OF RECYCLING USING THE BALANCED SCORECARD

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Abstract
Purpose: Recycling supply chain management (SCM) contributes to the improvement of environmental, economic, and social aspects. The purpose of this research is to evaluate the SCM of five recycling management associations (RMAs), two of which are recyclers by trade or formalized recyclers and three of which are in the process of formalization. Methodology/approach: The assessment of the RMAs' SCM was based on seven Balance Scorecard perspectives (BSC): financial, customer, internal processes, development, planning, environmental, and social. Information was collected through a multiple case study using a 55-question questionnaire. Findings: The results showed that the SCMs that make up the five RMAs have weaknesses in regulatory, technical, and operational aspects. Practical implications: Formalized RMAs need to improve their SCM to compete with large recycling operators and RMAs in the process of formalization, and this improvement is a step towards recognition as professional recyclers in Colombia. Originality/value: This is the first document that evaluates the SCM of the RMAs using seven perspectives of the BSC and involving two types of associations: formalized and those in the process of formalization.
Keywords: supply chain; recycling management; evaluation of supply chain management; balanced scorecard; multiple case study

1. INTRODUCTION

The management of recyclable waste by companies is a matter of concern for shareholders, customers and society, as inadequate waste management affects natural resources, human health and the company's reputation.

Recycling management has been studied from different approaches such as reverse logistics, supply chain (SC) sustainability and circular economy. In the first approach, Pereira et al. (2023) investigated the impact of recyclable waste management of electrical parts on war. Aliaga et al. (2021) proposed a model to optimize the

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collection of recyclable materials in cities where this activity is deficient. Dieste et al. (2018) designed a framework for reverse logistics of electrical waste and electronic equipment according to Brazilian legislation. The sustainability of reverse logistics in the management of solid waste generated by medical activities was studied by Elliazidi and Dkhissi (2024) using a multi-objective programming model. Wani and Mishra (2024) studied how biodiesel energy production using microwave technology improves the supply chain management (SCM) of municipal solid waste. The sustainability of reusable packaging was studied by Bradley and Corsini (2023), who proposed a framework that includes 22 factors that influence the sustainability of reusable packaging. Based on a circular economy approach, Omair et al. (2022) used a multistate linear programming model to improve the management of recyclable waste in the automotive industry. Islam et al. (2022) used the circular economy concept to identify and evaluate the business and research opportunities of the recycling business.

The aforementioned approaches show that the research on recycling has focused on material collection and the management of companies to improve this business. However, there is a gap in the research addressing the evaluation of SCM of recycling associations, which this study aims to fill.

The evaluation of SC has been conducted using models such as supply chain operations reference (SCOR), key performance indicators (KPI), analytic hierarchy process (AHP), and balance scorecard (BSC). According to Tippayawong et al. (2016), the SCOR model is a measurement model that focuses on four aspects (1) planning, (2) resources, (3) production, and (4) delivery. KPIs are used to measure the performance of one or more SC activities and are part of the BSC (Potekhi 2018). da Cruz et al. (2022) stated that AHP is a multi-criteria decision method that facilitates decision making based on expert judgments, pairwise comparisons, and evaluation of the consistency of these judgments. The BSC proposed by Kaplan and Norton (1996) has been used to evaluate the performance of SC using financial and non-financial aspects, this model is based on four perspectives: financial, customer, internal processes, and learning and growth.

Based on three aspects: 1) The research question to be answered is: How to evaluate the SCM of recycling management associations (RMAs)?, 2) that recycling management includes financial, non-financial, environmental, and social aspects, and 3) that the evaluation should use a method that facilitates the identification of the aspects on which SC managers should focus their efforts to improve the association, the modified BSC proposed by Saroha et al. (2022) who added the environmental and social perspectives will be used to evaluate the SCM of RMAs. The BSC has been used in studies such as that of Pejić Bach et al. (2023) which identified the degree of maturity of the SC. Rodríguez-Rodríguez et al. (2020) proposed a methodology to improve the efficiency of SC processes. Naimi et al. (2020) prioritized the important variables of SC reconfiguration by applying the BSC.

The evaluation of the SCM of the RMAs will be exploratory and descriptive and will be carried out using a multiple case study developed in the city of Santiago de Cali (Colombia). The selection of the RMAs will be made by judgment. To collect the information, a questionnaire will be used, consisting of 55 questions and closed answers and Likert scale.

The document has the following structure: section two shows the definitions of the concepts that are part of the study, section three deals with the methodology, section four shows the results, and ends with section five, which concludes and proposes future lines of research.

2. THEORETICAL BACKGROUND

This section discusses the three concepts used to assess the SCM of RMA: 1) SC, 2) SCM, and 3) BSC. In addition, some SC studies using BSC are presented.

2.1. Supply Chain

La Londe and Masters (1994) defined the SC as the set of firms that transmit materials. Producers of raw materials, semi-finished products, assemblers, wholesalers, traders, retailers, and transporters are part of the SC. For Chen and Paulraj (2004), a SC encompasses all the efforts involved in producing and delivering a product to the final customer. According to Goetschalckx (2011), a SC is an integrated network of resources and processes responsible for the acquisition of raw materials, transformation (to obtain intermediate and final products), and distribution of the finished product to the final customer. According to Corominas (2013), the SC

is a network of entities that work together to obtain, deliver, and possibly recover a product or set of products. For the SC Professional Council, the SC begins with raw materials without processing and ends with the end customer using the finished product. The exchange of materials and information in the logistics process extends from the procurement of raw materials to the delivery of finished products to the end user. All suppliers, service providers, and customers are links in the SC. (Vitasek 2013). The definitions of SC proposed by Corominas (2013) and the SC Professional Council are the basis for the study of RMAs.

2.2. Supply Chain Management

SCM has been defined from different perspectives. Mentzer et al. (2001) defined SCM as the systematic and strategic coordination of traditional business functions, taking into account the tactics used for these functions in a particular company and among companies participating in SC, in order to improve individual (company) performance and SC as a whole. Stock and Boyer (2009) defined SCM as a network of relationships within and between organizations and business units composed of material suppliers, purchasing, production, manufacturing, shop floor, logistics, marketing and related systems to facilitate the flow of product, money, and information from the initial producer to the final customer to achieve value-added benefits, maximize profits through efficiency and customer satisfaction. SCM is the management of relationships in a network of organizations, from the end customer to the original supplier, through key cross-functional processes to create value for customers and stakeholders (Lambert 2014). According to Lemay et al. (2017), SCM consists of the design and coordination of a network through which organizations and individuals acquire, use, deliver, and dispose of products, procure distribution services, and make their offerings available to markets and customers. The definition to be used in this case study is the one proposed by Stock and Boyer (2009).

2.3. Balance Scorecard

According to Kaplan and Norton (1996), the BSC is an evaluation method based on four measurement perspectives: i) financial, ii) customer, iii) internal processes, and iv) learning and growth. The financial perspective evaluates the organization from the perspective of shareholders; the customer perspective provides information on aspects such as customer acquisition, retention and satisfaction; the internal process perspective facilitates the evaluation of processes that contribute to customer satisfaction; and the learning and growth perspective evaluates the development of people, systems and organizational culture. Lu et al. (2018) stated that the BSC is a method that has been used in the evaluation of organizational performance and covers financial and non-financial aspects. However, issues such as sustainability and social responsibility of organizations have forced the inclusion of other perspectives such as environmental and social. For Saroha et al. (2022), the environmental perspective deals with the reduction of problems related to harmful raw materials, pollution, and polluting waste, while the social perspective is related to the improvement of the company's image based on social and environmental responsibility. According to Rasool et al. (2022) the use of BSC based on the seven perspectives mentioned above, on the one hand, facilitates the evaluation of the organization with a holistic view, and on the other hand, is a tool to improve the management of the company (Kumar et al. 2024).

2.4. Balance Scorecard in the Supply Chain

The use of BSC in SC evaluation has been carried out from approaches such as performance evaluation, sustainability, and waste management. Tippayawong et al. (2016) used BSC as one of the models to evaluate green SC in the Thai auto parts industry. Lu et al. (2018) measured and improved the sustainable performance of an international airport through the four perspectives of BSC. Aliakbari Nouri et al. (2019) to assess the sustainability of the chain proposed a framework in which the four perspectives of BSC and the economic, social and environmental dimensions of sustainability were integrated. Maheswari et al. (2020) proposed various BSCs to measure the sustainable reverse logistics performance of organizations managing e-waste. Tsai et al. (2020) used the concepts of BSC and sustainability to explore the hierarchical relationships of integrated solid waste management in utilities in Vietnam. Balaji et al. (2021) derived the performance of a manufacturing company using the financial and non-financial measures of BSC. Rasool et al. (2022) synthesized the metrics used to evaluate the performance of digital SC. Bui (2024) conducted the evaluation of the sustainable SC transparency practices of the semiconductor industry in Taiwan by applying the four BSC perspectives.

3. RESEARCH METHODOLOGY

According to Kumar (2019), the main objective of qualitative research is to understand, explain, explore, discover, and clarify situations, feelings, perceptions, attitudes, values, beliefs, and experiences of a group of people. Therefore, this approach is suitable for assessing the SCM of RMAs because it facilitates understanding how chain processes are managed. The assessment is carried out using a case study, which facilitates knowing the context of an everyday situation and recognizing patterns of the topic being analyzed (Yin 2017). The everyday situation that was addressed is the activity of recycling paper, cardboard, metal, glass, or plastic, and the recognition of patterns was made in activities such as: planning of recycling collection, recruitment, and sale of recycled material. Five RMAs participated in this case study, so it is a multiple case study. According to Rashid et al. (2019) and Fink et al. (2022), this type of case facilitates the generalization of findings.

The recycling SCM case study has been used in several contexts: Iurato and Schanz (2024) examined the role of industry associations that produce, process, and manage waste in an established and emerging post-consumer recycling market. Türkten (2023) investigated the potential to generate additional income from tomato waste recycling along the SC and analyzed the impact of such additional income on reducing financial inequality among chain actors. Liu et al. (2022) proposed a multi-criteria decision-making approach based on fuzzy sets and the VIKOR method to design an inverse SC for the recycling of medical waste generated in the coronavirus disease (COVID-19) pandemic.

3.1. Case Selection

The multiple case study was carried out in the city of Santiago de Cali, Colombia; among 32 cities, Cali ranks fourth in terms of competitiveness (Maiguashca & Garcia 2021). Based on the fact that the purpose is to evaluate the SCM of recycling, the RMAs are the unit of analysis in this multiple case study. The five RMAs were selected because, out of a total of 33 associations belonging to the Vision 3030 Collective, which is part of the National Association of Colombian Businessmen, they expressed interest in participating in this study. The other 28 associations gave three reasons for not participating in the project. 1) on previous occasions, the RMAs had provided all the information on recycling to public officials, who subsequently created companies that competed with the associations; 2) in other cases, the participating universities did not complete the project; and 3) they did not identify with the benefits they would obtain by participating in this multiple case study.

The economic activity of the RMAs involved in this multiple case study is the recycling of paper, cardboard, metal, glass, or plastic. Three of the associations are in the process of formalization and two are formalized. The association in the process of formalization was understood as the organization that partially complies with the requirements mentioned in Decree 596 to be an official manager. Formalized association is the organization that complies with the operational scheme of harvesting activity mentioned in Decree 596. Table 1 shows the status of each association.

TABLE 1 - STATUS OF THE RMAS PARTICIPATING IN THIS CASE STUDY.

Case	State
A	In the process of formalization
B	In the process of formalization
C	In the process of formalization
D	Formalized
E	Formalized

3.2. Data Collection

In this multiple case study, eight steps were followed in the process of data collection and analysis: 1) preparation of the questionnaire, 2) validation of the questionnaire by the staff of the working team and the VISION 3030 Collective, 3) presentation of the case study to the RMAs, 4) meeting with the RMAs to answer the questionnaire, 5) processing the information, 6) analysis of the results, and 7) meeting with the RMAs and the staff of the VISION 3030 Collective to verify the results obtained. According to Kähkönen (2011), the verification of the results ensures the validity of the construct. The data analysis was carried out using the statistical software Statistical Package for Social Sciences (SPSS) and Microsoft EXCEL spreadsheet. The information collected from each questionnaire was first analyzed individually and then cross-checked between

questionnaires to identify commonalities and differences between cases. The analysis of the responses to the questionnaires used sources of information such as reports published in newspapers, association websites, literature review on the subject under study, and information on the recycling market. The consultation of the sources of information led to three ways of triangulating the data. 1) The consultation of the websites of the organizations and the recycling market facilitated the comparison between the information obtained from the questionnaires and the published information on recycling management; 2) the literature review contrasted the results obtained in this case study with the published results on recycling management., and 3) in the process of data collection and analysis, a database was created and the chain of custody of the information was ensured. According to Yin (2017), both aspects increase the reliability of the case study.

3.3. Structure of the Questionnaire

This section describes the two parts of the questionnaire structure used in this case study. In the first part, six questions dealt with the characterization of the RMAs, and in the second part the questions of each perspective.

The characterization of the target population included questions to define aspects such as the type of association, whether formalized or not; the urban areas covered by the RMAs; the type of material recycled; the activity carried out by the association, whether it is collection, commercialization or recruitment; the quantities of recyclable material recovered; and the activities that limit the management of the association.

TABLE 2 - ASPECTS OF BSC INCLUDED IN THE QUESTIONNAIRE

Perspective	Target	Aspect Inquired
Financial (7)	Identify the economic performance of the different processes of the SC of RMAs. 0	Process that generates the highest cost, average monthly revenue, frequency of comparison of revenue and costs, fastest growing variable in the organization, logistics costs.
Customer (7)	Identify the main customers and their degree of satisfaction with the services provided.	Identification of the main customers, degree of satisfaction with the service provided, compliance with customer requirements, delivery time of recycled material, scheduling of a collection of recyclable materials, a variable that hinders the proper delivery of raw material to customers.
Processes (13)	To know: 1) the processes carried out by the RMAs throughout their SC, 2) the different problems they present, and 3) the appropriate solution provided to them.	Identification and evaluation of problems occurring in collection, problem-solving time, agility to adapt to changes, supplier selection, level of satisfaction with current process management, loading, and unloading of recycling, instructions for care and handling of raw material, frequency of theft and loss of recycled material, facilities, collection route.
Development (10)	Identify the degree of relevance given by the RMAs to training and education activities regarding waste management and handling of specialized machinery. To determine whether managers monitor and evaluate management processes in order to introduce improvements.	Skills in handling machinery or previous knowledge of the recycled raw material management process, frequency of training, process evaluation, collection, analysis, and storage of information, main problem in their productive activity, reasons that prevent them from complying with occupational health and safety standards, limitations for proper tax management, business strengthening plan, compliance with minimum administrative aspects according to Decree 596, training in the handling and quality of materials.
Planning (3)	Evaluate the degree of planning of process activities.	Work planning, SC risk, rate of material delivered to customers, rate of material rejected by customers.
Environmental (6)	Identify the way in which each employee appreciates and values his or her environment.	Natural resource of higher consumption in the production process, final disposal of rejected material, environmental initiatives, actions to reduce the carbon footprint.
Social (9)	To understand the interaction of the RMAs with the communities and the contribution they have on the communities.	Work with communities, contribution to community development, use of media to disseminate information on separation of recyclable waste, criteria, and quality standards for the use of waste.

Due to the fact that the RMAs included in this study carry out both financial and non-financial activities, the BSC proposed by Kaplan and Norton (1996) proved to be an appropriate model for assessing the SC of these associations. However, since recycling involves environmental and social aspects, the basic BSC model was complemented with the environmental and social perspectives proposed by Saroha et al. (2022). Therefore, in the second part of the questionnaire, information was collected from the following perspectives: financial, customer, internal processes, development, planning, environmental, and social, with the aim of evaluating the SC processes of the RMAs. Table 2 shows in column 1 the BSC perspective, in column 2 the objective of the questions, and in column 3 the aspects of each perspective that were examined. The number in brackets below the name of the perspective indicates the number of questions used to assess it.

Eight response options were used in the questionnaire. 1) single answer option, 2) multiple choice, 3) complete, 4) dichotomous answer yes, no and don't know /no answer with justification, 5) Likert scale of satisfaction, 6) Likert scale of frequency of repetition, 7) Likert scale of difficulty and 8) Likert scale of importance. Column 4 shows the question number and column 5 shows the answer option for the question.

3.4. Supply Chain Processes of Recycling Management Associations

This section describes the collection, packaging, and marketing processes of the cardboard, plastic, metal, and glass RMAs involved in this case study, which facilitate the recovery of value from waste discarded by consumers. The waste is collected with the aim of reusing it either as a raw material or as parts to be used in the companies' production cycles.

The SC starts with the identification of the producers of the material to be recycled; for non-formalized RMAs, the main suppliers are production or service companies, residential units or households, and for formalized RMAs, the industrial and commercial sectors and RMAs. On the basis of secondary information, it was found that the main reason for selecting these suppliers is the volume capacity in raw materials that they provide. The next link in the chain is the collection process, which is carried out by subsidiaries of the RMAs. To collect the material, a collection route is planned where the collected material is transported in tricycles, motorized vehicles, or trucks.

The recycled material is transported to a warehouse or to a sorting and recovery station. Once managers have the recycled material, they start the enlistment process, which involves four activities. 1) cleaning and sorting, 2) separating and packaging each type of material, 3) weighing on scales, and 4) storage. The next link in the chain is the marketing process, which consists of distribution or sale. In the distribution process, the material is taken or collected by the personnel of the processing companies and/or factories, while the sale takes place when someone expresses interest in buying the recycled material directly from the warehouse or recycling station. Recycled material that is not sold is sent to final disposal for collection by sanitation companies. Figure 1 shows the schematic of the SC processes described above.

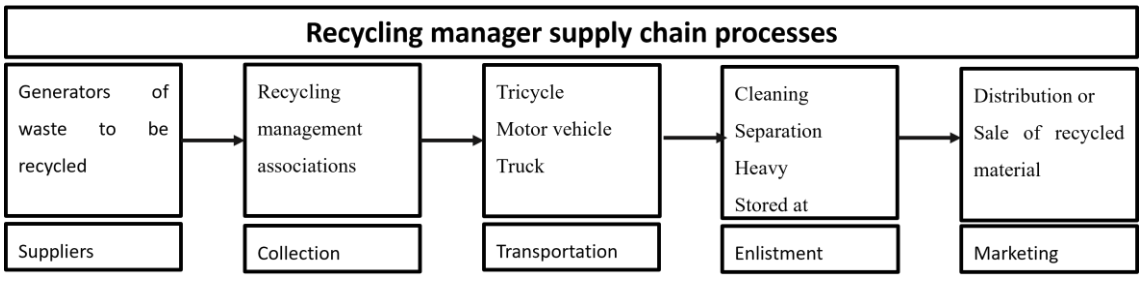

FIGURE 1 - SC PROCESSES OF RMAS

Cases A, B, and C carry out the collection, transport, enlistment, and marketing processes. Cases D and E concentrate their capacities on the processes of collection and marketing, sometimes collecting and transporting recycled material. The associations of cases A, B, and C are sometimes suppliers to cases D and E. Depending on the type of material, it is stored in warehouses or in the open air. The average quantities of material recycled each week are shown in Table 3.

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TABLE 3 - AVERAGE AMOUNTS OF MATERIAL RECYCLED

	Quantity of material recycled on average per week (Kg)				
Type of association	**CARDBOARD**	**METAL**	**PLASTIC**	**GLASS**	**OTHER**
Non-formalized association	2.177,33	2.100,00	2.008,33	2.002,67	753,00
Formalized association	8.500,00	1.100,00	3.200,00	175,00	2.525,00

The processes through which the recycled material passes are described below in a flow chart by stages. The first stage corresponds to the generation of cardboard, plastic, metal or glass waste that needs to be collected. In the second stage, the enlistment activities are carried out. It also assesses whether the collected material meets the requirements for sale to companies transforming recycled material. At the third level, the sales and final disposal processes of the material that is not suitable for sale are carried out. Figure 2 shows the flow diagram of the management of recycled material described above.

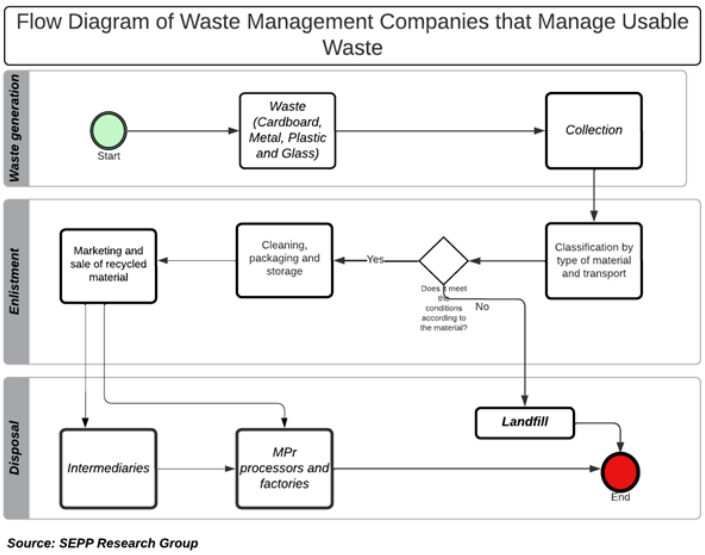

FIGURE 2 - FLOWCHART FOR THE MANAGEMENT OF RMA

4. RESULTS

This section presents the results of the evaluation of the SC of RMAs based on seven BSC perspectives: financial, customer, process, development, planning, environmental, and social.

4.1. Financial Perspective

The results showed that the non-formalized RMAs consider that the processes that generate the highest costs are: raw material collection, transportation, preparation, and purchase of raw materials, while the formalized associations consider raw material collection, storage, and labor contracting as the most costly.

The raw material that generates the highest average monthly income in the formalized associations is cardboard, while the non-formalized associations agree that there are no significant differences in the income obtained from cardboard, plastic, and metal.

Regarding the aspects with the greatest growth in recent years, the non-formalized managers consider that they are: the number of suppliers, the quantity of raw material processed, hired labor, and machinery acquired, while for the formalized managers they are: the number of suppliers and the raw material to be processed.

With regard to logistics costs, it was observed that the non-formalized RMAs do not have a defined frequency for estimating these costs, but they do so in order to calculate cost overruns and to make a monthly comparison; in the case of the formalized associations, they do so as an input for the analysis of the cost of sales and for the measurement and control of profitability.

Table 4 shows in column 1 the aspect evaluated by the perspective and in columns 2 and 3 the evaluation made by the managers of the recycling associations.

TABLE 4 - FINANCIAL PERSPECTIVE EVALUATION OF THE RMAS

Aspect evaluated	Non-formalized association		Formalized association	
Process that generates higher cost.	Collection of raw material, transportation, preparation, and purchase of raw material.		Raw material collection, storage, and labor contracting.	
Higher average monthly income.	Material	Income	Material	Income
	Cardboard	$2027.00	Cardboard	$324.31
	Plastic	$210.08	Plastic	$237.02
	Metal	$235.41	Metal	$212.04
	Glass	$19.80	Glass	$99.77
Frequency of comparison of revenues and costs.	Weekly		On a weekly basis and according to market variation.	
Variable with the highest growth in the association.	Number of suppliers, quantity of raw materials processed, labor hired and machinery purchased.		Number of suppliers and raw materials processed.	
Frequency of estimation of logistics costs.	They have not defined it.		Frequent.	

4.2. Customer Perspective

The main clients of formalized managers are packaging companies, and for non-formalized managers they are formalized associations, commercial sectors, packaging companies, other collectors, and footprint managers.

Regarding the service provided to clients, it was found that 100% of clients of formalized associations are satisfied with the service provided by the management company, while 33% of clients of non-formalized companies are indifferent to the service provided and the remaining 67% are satisfied.

The results showed that in both non-formalized and formalized management associations, the reasons for verifying that the recycled material meets the client's requirements in terms of quality, quantity, and delivery time are to avoid rejections and to ensure a lasting business relationship.

TABLE 5 - EVALUATION OF THE CLIENT PERSPECTIVE OF RMAS

Aspect evaluated	Non-formalized association		Formalized association	
Main customers	Customer	Percentage (%)	Customer	Percentage (%)
	Packaging companies	44	Associations of recyclers	20
	Construction companies	14	Commercial sectors	20
	Other associations	14	Other associations	20
	Other collectors	14	Other collectors	20
	Individuals of the common	14	Packaging companies	20
Satisfaction with the service provided to its customers.	67% satisfaction with the service provided. 33% are indifferent to customer satisfaction.		100% satisfaction with the service provided.	
Verification of compliance with customer requirements.	Yes		Yes	
Delivery time of recycled material.	Four to six days		Four to eight days	
Ease of scheduling a collection route.	Variable	Degree of difficulty	Variable	Degree of difficulty
	Staff	Indifferent	Staff	Easy
	Transportation	Indifferent	Transportation	Easy
	Security	Indifferent	Security	Very easy
	Other	Indifferent	Other	
Reasons that make it difficult to deliver material to the customer.	Do not handle customer's distribution and closing hours.		Inbound logistics, marketing and non-distribution management.	

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In terms of delivery time, the non-formalized waste management companies deliver glass in less than four days, plastic in five to six days, metal in six to seven days, and cardboard in less than three days. The delivery time of formalized collectors is more than eight days for glass and plastic, between eight and nine days for metal, and less than four days for cardboard.

Regarding the planning of the collection of recycled materials, the most difficult processes to plan for the non-formalized waste management companies are personnel and transport, while for the formalized waste management companies no process is difficult to plan.

The non-formalized management companies agree that the difficulties in delivering to their clients are the fact that they do not handle distribution, and the closing hours of the client's company, while in the formalized management associations the difficulties are reception logistics, marketing, and the fact that they do not handle distribution. Table 5 shows the results of the evaluation of the client's perspective.

4.3. Process Perspective

Regarding the evaluation of the problems in the collection process of recyclable materials, the results showed that the non-formalized RMAs are the mixing of recyclable materials with non-recyclable materials with 40% and the lack of personnel for the collection of recyclable materials with 20%. Other problems faced by these associations are transport failures and lack of raw materials. 40 percent of the formalized associations have problems due to the mixing of recyclable materials with non-recyclable materials and the shortage of recycled materials, and 20% face the problem of the purchase price offered by competitors. Figure 3 shows the problems evaluated by SC managers to anticipate future risks.

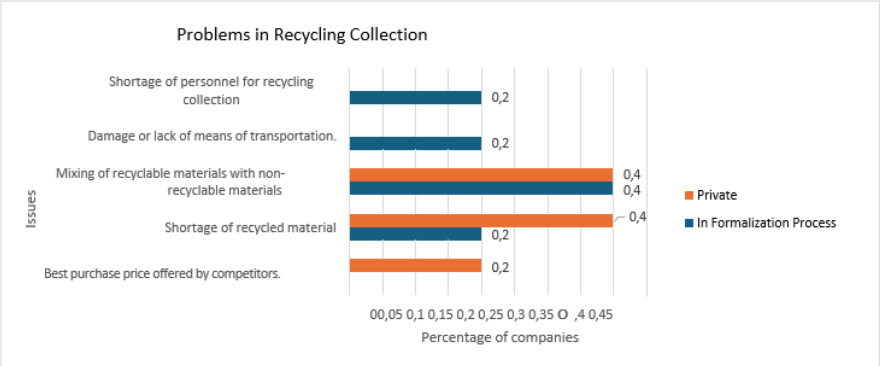

FIGURE 3 - PROBLEMS OF THE RMA SC PROCESSES

The results showed that non-formalized and formalized RMAs take between one and three days to resolve problems in the recycling collection process.

Regarding the time to adapt to changes, non-formalized RMAs have a time to adapt to regulatory changes of more than ten days; for technical changes, it was observed that 50% of these companies take between six and seven days, the other 50% take more than ten days to adapt to these changes. Of these associations, 66.7% take between one and three days to adapt to operational changes, and the remaining 33.3% take between six and seven days. In the formalized RMAs, it was observed that it takes more than ten days to adapt to regulatory changes. Of these, 50% need between one and three days to adapt to technical changes, while the other 50% need more than ten days. Adapting to operational changes in these associations takes between one and three days. Figure 4 shows the adaptation times discussed above.

Regarding the degree of satisfaction with the processes, it was found that both associations are moderately satisfied with the way the distribution and sales processes are carried out and are satisfied with the recruitment, supplier, and transportation processes.

The Personnel that the associations have available to handle the recycled material and the products offered, it was found that all associations have trained personnel for handling and loading, and unloading products. The training of the members was provided by the Vision 3030 Collective and the National Apprenticeship Service, which certifies them in work skills.

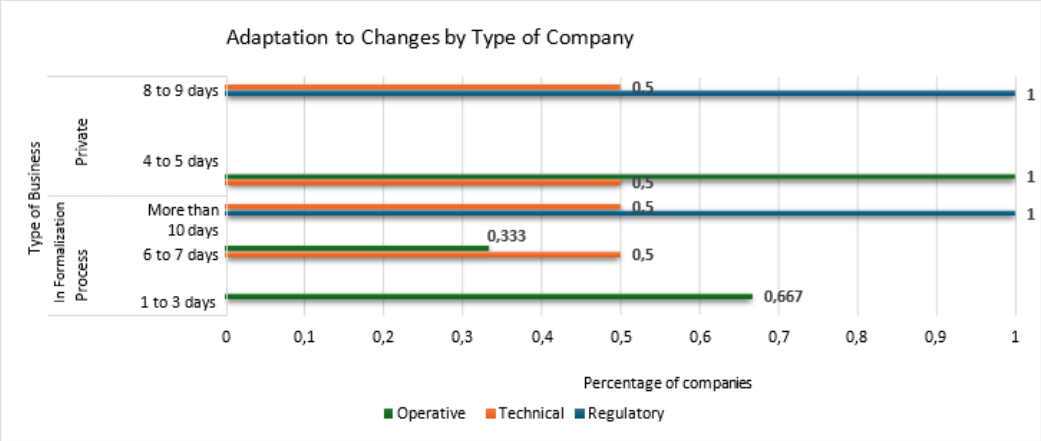

FIGURE 4 - TIME OF ADAPTATION TO CHANGE OF THE RMA

Concerning the development of guidelines for handling and care in the recycling processes, the results showed that 66.7% of the non-formalized associations develop manuals and 100% of the formalized associations do the same. The main reasons why the studied associations have manuals are to design a process map, to carry out practices, and to guarantee the efficiency of the process.

The results showed that theft and losses are rare in both associations. Losses are due to differences in weighing of material by suppliers, unusable recycling, and material quality.

Related to the aspects that affect the collection route of recycled material, the results showed that for both types of associations it is the cost of maintaining the means of transport, highlighting that this has a greater impact on the formalized associations. 100% of the formalized associations agree that what most affects their collection routes are the payment of tolls and the maintenance of the means of transport, and 50% are affected by the fixed costs of handling recycled material.

For 66.7% of the non-formalized associations, the aspects that most affect their collection routes are the cost of maintaining the means of transport and the cost of fuel. In addition to the above-mentioned factors, 33% of the non-formalized associations emphasize that the deterioration of the roads causes them to take longer to transport raw materials. Figure 5 shows the aspects that affect the collection route of the RMA.

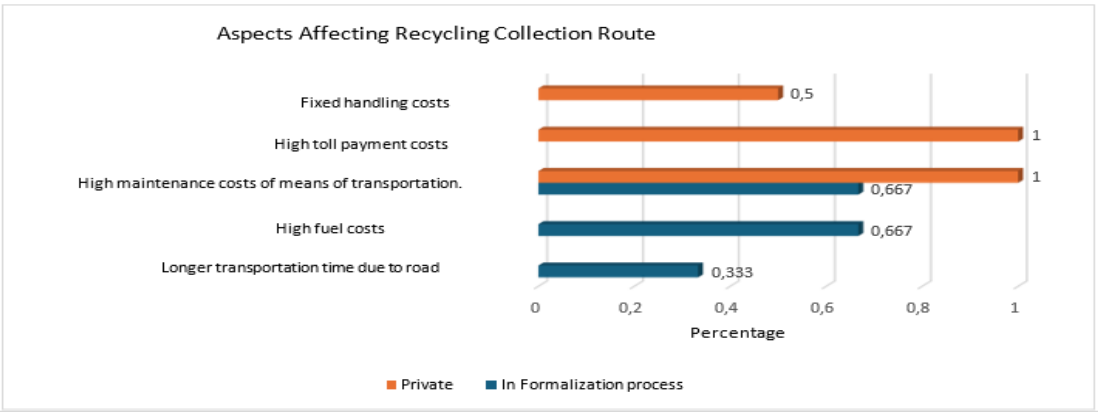

FIGURE 5 - ASPECTS AFFECTING THE RMAS COLLECTION ROUTE

4.4. Development Perspective

The results showed that formalized and formalizing RMAs place a high value on the fact that their employees and partners have machine skills or prior knowledge in the process of managing recycled raw materials. In addition, it was found that formalized RMAs frequently give lectures to their employees on the importance and management of materials such as cardboard, plastic, metal, and glass, while non-formalized RMAs occasionally give lectures on the aforementioned topics.

TABLE 6 - ASPECTS EVALUATED FROM THE PERSPECTIVE OF THE PROCESSES OF THE RMAS.

Aspect evaluated	Non-formalized association		Formalized association	
Degree of importance of possessing skills in handling machinery or knowledge of recycled material management.	Very important		Very important	
Frequency of training.	Frequently		Occasionally	
Frequency of evaluation of the processes of the SC of the RMAs.	Process	Frequency	Process	Frequency
	Collection	Occasionally	Collection	Frequently
	Suppliers		Suppliers	
	Transportation and assembly		Transportation and assembly	
	Distribution and sales		Distribution and sales	
Recycled material rejection rate.	Material	Percentage (%)	Material	Percentage (%)
	Cardboard	20	Cardboard	20
	Metal		Metal	
	Plastic		Plastic	
	Glass		Glass	
Collection, analysis and storage of information.	Manually, in the cloud, Microsoft Excel and specialized software			
Problems in the processes of the SC of the RMAs	Process	Problem	Process	Problem
	Recycling	Combination of non-recyclable waste with recyclable waste and lack of disposal in residential units.	Recycling	Operating cost
	Transportation		Transportation	
	Suppliers	Procurement of raw material that complies with quality conditions.	Suppliers	Procurement of raw material that complies with quality conditions.
	Enlistment	Selection and distribution of material in the warehouse. Lack of process analysis. Lack of conveyor belt.	Enlistment	They have no enlistment problems.
	Distribution and sales		Distribution and sales	
Business strengthening required by Decree 596 of 2016.	Appearance	Defined	Not applicable	
	Objectives	Yes		
	Goals			
	Activities			
	Timelines			
	Costs			
	Sources of financing			
Minimum administrative aspects in accordance with Decree 596 of 2016.	Appearance	Defined	Not applicable	
	Portfolio of services	Yes		
	User databases			
	Supervision and operational control systems			
	Labor competencies			
	Website	No		

Regarding the frequency with which the processes of management of recycled materials are evaluated, it was found that the RMAs in the process of formalization occasionally evaluate the processes of distribution, sale, transportation, and preparation of raw materials and suppliers of recycled materials, while the formalized

associations frequently evaluate the processes of transportation, preparation of raw materials and collection of recycled materials; the processes of distribution, sale, and suppliers are occasionally evaluated.

The results that address the material rejection showed that in both associations the percentage of rejection of cardboard, glass, metal, and plastic delivered to their customers is less than 20%.

Regarding the collection, analysis, and storage of information, it was found that in both formalized and non-formalized associations, information is managed manually and in the cloud, and Microsoft Excel and specialized software are used.

The results showed that the main problems of the non-formalized associations in the recycling activity are the combination of non-recyclable wastes, the lack of disposal in the residential units for the delivery of recycling to the waste managers, and the transportation of the material. In private associations, the main problem in recycling activity is the high cost of operation.

Regarding the suppliers, the main problem for both types of associations is the procurement of raw materials that meet the quality requirements. The non-formalized associations considered that the main problems in the enlistment process are: the mixture of recycled material, which makes the selection difficult, the distribution of the material in the warehouse, the lack of analysis in the collection process, and the lack of a conveyor belt to reduce the time required for this process.

Respecting the business strengthening plan required by Decree 596 of 2016, which deals with the "Scheme of the activity of use of the public sanitation service and the transitional regime for the formalization of waste pickers," the associations in the process of formalization have defined six aspects to strengthen: 1) the plan of objectives, 2) the plan of targets, 3) the plan of activities, 4) the schedule, 5) the plan of costs and 6) the plan of sources of financing. The reasons why they have defined the six aspects previously mentioned are to have clarity on the processes, to know the real result of the process, to advance and improve, to define action plans for the fulfillment of the goals, to have a better control of the activities, for the profitability of the business and to improve the financial strength of the association.

Regarding the compliance with the minimum administrative requirements listed in Decree 596, the associations in the process of formalization comply with the service portfolio, the user database, the supervision and operational control systems, and the work competencies. The reasons that motivated the associations to comply with these requirements are to improve the targeting of the services they offer and to work on safe and efficient processes to improve productivity. The website requirement was not met due to lack of management. Table 6 shows the results of the evaluation of the customer perspective in the RMAs.

4.5. Planning Perspective

Regarding the frequency of work planning, the non-formalized associations have not determined it, while the formalized associations plan their work frequently.

The results showed that in the non-formalized RMAs the main SC risk is presented in the processes of suppliers, recruitment, and delivery times. While in the formalized associations it is the storage of raw materials and suppliers. Figure 6 shows the risks faced by RMAs.

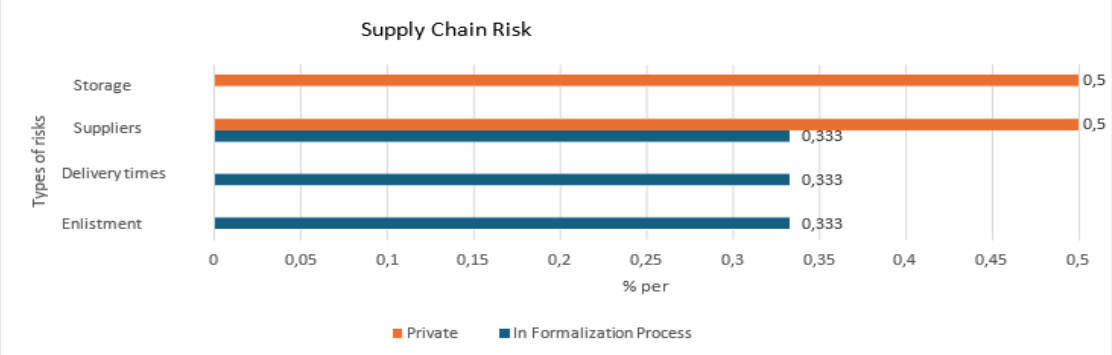

FIGURE 6 - RISKS OF THE SC OF RGAS

The results showed that in the non-formalized associations the frequency of rejection of recycled material delivered to their customers is not determined, and in the formalized associations the customer rarely rejects the material.

4.6. Environmental Perspective

Regarding the natural resource that is most consumed in the production process, the non-formalized associations indicated that this resource is fuel, while in the formalized associations it is energy.

Concerning the final disposal of the recycled material rejected by the customers, in the non-formalized associations this is done by the sanitation and landfill operator. In the formalized associations, the final disposal of the raw material is the reprocessing and the collection cart, depending on the condition of the material.

In terms of environmental initiatives, formalized associations very often carry out activities to reduce energy consumption, often participate in environmental clean-up days in their community, and collaborate with other marketers and institutions in waste management. Associations in the process of formalization often reduce energy and water consumption and collaborate with other marketers and institutions in waste management.

The results showed that non-formalized RMAs rarely take actions that contribute to the reduction of the carbon footprint, and formalized associations occasionally take such actions.

The actions taken by non-formalized associations to reduce their carbon footprint are preventive maintenance of means of transportation, reduction of paper consumption, replacement of lighting fixtures, and water reuse. In the formalized associations, they are environmental education for personnel, turning off unnecessary lights, turning off cars at stops, reducing downtime, improving the efficiency of collection routes, and preventive maintenance. Table 7 shows the results of the environmental perspective mentioned above.

TABLE 7 - ASPECTS EVALUATED IN THE ENVIRONMENTAL PERSPECTIVE OF THE RMAS

Aspect evaluated	Non-formalized association		Formalized association	
The most consumed natural resource.	Fuel		Energy and fuel	
Final disposition of rejected recycled material.	Type of layout	Percentage(%)	Type of layout	Percentage (%)
	Landfill	33.3	Collecting cart	50
	Janitorial operator	33.3	Reprocessing	50
	Garbage collection	33.4		
Participation of associations in environmental initiatives.	The associations frequently participate in initiatives such as clean-up days, collaboration with other associations and institutions to provide training in waste management and reduction of water and energy consumption.			
Reduction of carbon footprint.	They rarely take actions to reduce their carbon footprint.		Occasionally they take actions to reduce their carbon footprint.	
Actions to reduce the carbon footprint.	Preventive maintenance of means of transport Reduction of paper consumption. Change of lighting fixtures. Water reuse.		Environmental education for personnel. Switching off unnecessary lights. Trolleys turned off at stops. Reduction of downtime. Improve efficiency in collection routes. Preventive maintenance.	

4.7. Social Perspective

The results showed that the non-formalized management associations work with nearby communities such as the vulnerable population, street recyclers, and victims of the conflict. Formalized associations work with rural and urban population, street recyclers and schools.

In terms of contribution to the communities, the results showed that the non-formalized and formalized associations contribute to the communities by generating employment. Formalized associations also educate and raise awareness about the importance of recycling.

5. DISCUSSIONS

Based on the fact that the purpose of this research is to evaluate the SCM of RMAs, in this section we discuss the results of this evaluation from seven BSC perspectives: financial, customer, internal processes, development, planning, environmental, and social.

Bhagwat and Sharma (2007) stated that financial performance measures indicate whether the execution of strategies effectively contributes to the improvement of a company's bottom line. Based on the financial aspects evaluated, the improvement of the financial management of RMAs is based on increasing the number of suppliers of recycled material and increasing the amount of material to be recycled. According to Potekhi (2018) the financial indicators show the organization's ability to generate money; for the RMAs the recycled materials of cardboard, glass, and metal generate the most money. Indrawati et al. (2018) stated that they make part of the financial perspective the aspects that affect the cost each time the process is carried out, for both associations the process that affects the cost is the collection of raw materials. However, there are differences in other variables that affect the cost such as transportation, storage, purchase of raw material and hiring of labor. This difference is due to the fact that in the non-formalized RMAs the lack of means of transportation and storage warehouses increases the cost of the process, while in the formalized associations the variability of labor and having a warehouse to store the recycled material affects the cost of storage.

Rodríguez-Rodríguez et al. (2020) suggested that the customer perspective addresses the relationship between the SC and the customers. The relationship between recycling managers and clients has occurred in two ways. In the first case, the relationship between formalized associations and clients showed 100% satisfaction and in the case of non-formalized associations, the relationships are not important for 33% and for 67% these relationships are important; this difference is due to the fact that formalized associations have a direct relationship with the client who buys the recycled material to transform it again and in the case of non-formalized associations the clients are other management companies and the sorting and recovery stations, therefore the contact with the final client rarely occurs. Variables such as quality and delivery times were also addressed from the customer's perspective; both recycling management associations agreed that these facilitate the maintenance of long-term relationships with customers and the reduction of waste. Pejić Bach et al. (2023) stated that quality and delivery times improve customer satisfaction. In this line of thinking, for Israel et al. (2023) customer service is the central part of SCM. Therefore, the customer perspective of BSC facilitates that SCM is customer-centric.

Bhagwat and Sharma (2007) stated that the internal process perspective analyzes the key business processes that affect customer satisfaction. The following aspects were analyzed in this perspective: problems of recycling SC processes, level of satisfaction with the execution of the processes, variables affecting the recycling process, and loss of material. Regarding the problems expected by the recycling SC managers, both associations agreed that two aspects affect customer satisfaction. 1) The mixing of recyclable materials with non-recyclable materials and 2) the lack of personnel for recycling collection. The first aspect increases the time of the collection and cleaning process, and the second aspect increases the time of the collection process, thus increasing the cycle time of the whole process, which leads to non-compliance with the delivery of material to the customer. Balaji et al. (2021) confirmed that the lack of trained personnel affects the process performance and Bradley and Corsini (2023) highlighted that one aspect that affects the reuse of cardboard packaging is the material preparation and cleaning processes.

Associations need between three and ten days to resolve regulatory, technical or operational issues. Part of the solution is also to strengthen the skills of the personnel, which is why they provide training on topics such as loading and unloading of material and provide guides for each of the processes carried out in the chain.

Regarding material theft and losses, both associations agree that these are due to differences in weighing by suppliers, unusable material, and process losses due to the quality of the recycled material. Bradley and Corsini (2023) suggested that losses and theft in the recycling process are caused by lack of training of personnel and poor process management.

The collection process of recyclable material carried out by both associations is affected by aspects such as fuel costs, maintenance costs of transportation means, costs of tolls, and fixed costs of handling recycled material. Książek et al. (2021) agreed that the previously mentioned operational costs affect the cost of the recycling collection route. Another aspect that affects the recycling process is the deterioration of the roads. According to Marseglia et al. (2022), the aspects that affect recycling collection should be taken into account in municipal waste management policies aimed at reducing transportation costs and environmental benefits.

According to Indrawati et al. (2018) the development perspective includes human resources and information systems. The human resources of both associations are trained on topics such as the importance and management of recycled materials, for Naimi et al. (2020) these trainings increase employee satisfaction. The management of information systems throughout the recycling SC is done manually or using software. Some aspects of information management that have been developed using software are the service portfolio, user database, documentation for operational monitoring and control, and labor competency management, for Tizroo et al. (2017) this management facilitates the tracking and tracing of recycled materials.

In both associations, although with different frequencies, the processes of transportation, collection of recycled material and collection, distribution and sales, and suppliers are evaluated. One aspect that is rarely evaluated is the amount of material rejected by customers. The evaluation showed that SC recycling managers face various problems either with recycled material suppliers, internal processes or customers. According to Naimi et al. (2020), the evaluation of processes facilitates the planning of future scenarios. The planning of future scenarios based on the results of the assessment in associations in the process of formalization includes aspects such as objectives, goals, activities, timeline, costs, and sources of funding, for Saroha et al. (2022) evaluation is an essential tool of an organization that provides information to decision makers to propose future strategic plans.

The planning of future scenarios is done in both associations but with different frequency, in this planning it is analyzed how to reduce the risk in the supplier processes, recruitment and delivery times.

From an environmental point of view, we have identified two natural resources that are the most consumed in the recycling process. In the associations in the process of formalization it is fuel and in the formalized associations it is energy. The difference is due to the fact that the associations in the process of formalization carry out the collection of recycled material and the distribution and sale process more frequently, while the formalized associations dedicate more time to the preparation process. The use of these two resources is a warning to RMAs because processes such as collection and packaging can have a negative impact on environmental sustainability (Bradley & Corsini 2023). However, the associations are carrying out activities to reduce the consumption of these resources.

This final disposal management is in line with the view of Saroha et al. (2022) who stated that the ability to properly dispose of a product at the end of its useful life is important to avoid the negative consequences of improper disposal. The RMAs that do not provide adequate end-of-life management expose themselves to fines and sanctions such as temporary or permanent closure of the association.

Regarding the carbon footprint, both associations usually do not take measures to reduce it and rarely implement strategies in the transportation and procurement processes. According to Rebs et al. (2018), the implementation of actions to comply with limits on carbon emissions can contribute to meeting customer expectations. In addition, associations need to reduce this footprint in order to avoid paying pollution taxes.

From a social perspective, both associations provide job opportunities to both rural and urban communities, as well as to the displaced population. In addition, awareness campaigns are conducted with the communities on the importance of recycling. Saroha et al. (2022) found that working with communities facilitates the associations' social responsibility and promotes customer retention and loyalty.

6. CONCLUSIONS

In this case study, the BSC proved to be an appropriate method for assessing the SCM of the RMAs. In addition, it was shown that the seven perspectives of the BSC: financial, customer, internal processes, development, planning, environmental, and social, facilitate the evaluation of the management of RMAs.

Through the analysis of the seven perspectives, it was identified that the RMAs have weaknesses in compliance with the standard that regulates recycling and in strategic, technical, and operational aspects of the SC.

Two weaknesses of this study are: the small number of RMAs that responded to the questionnaire, and the fact that the SCM assessment of RMAs was performed using only the BSC. To overcome these weaknesses, four lines of future research are suggested: 1) carry out the SCM assessment with more RMAs, 2) use other statistical methods to assess SCM so that the results of each perspective can be compared between the two methods, and 3) combine the BSC with evaluation techniques such as the focus group or expert judgment to collect and analyze the results.

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DATA AVAILABILITY STATEMENT

Documents supporting the findings of this study are openly available in the Scopus and Web of Science databases. The books cited are available in the digital repositories of the Universidad Nacional de Colombia. Due to privacy policies, questionnaire responses are not published.

CONFLICTS OF INTEREST

The authors report there are no competing interests to declare.

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