Integration of different collaterals in a sustainable manner: a Multi Criteria Decision Approach

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Preliminary and Incomplete
This Version: May 1st, 2013

Abstract

Loan collateral-assets are critical complementary bank credit instruments, aiming at supporting and securing the uninterrupted service of a respective loan facility. Should a borrower proceed to default, collateral-assets provide critical last resort sources for bank loan recovery. Nevertheless, collaterals may provide least protection when they are most needed. Recessionary economic cycle phases, unstable capital markets, liquidity constraints and financial crises amplify abrupt downward collateral value shifts, resulting to intensified volatility and risk in the bank loan portfolio. This, in turn, can lead outstanding loans being exposed to diminishing collateral values, substantially increasing the bank's asset-liability mismatch and credit risk sensitivity. This paper proposes a consistent and integrated framework for the appropriate collateral-asset selection process in matching bank loan portfolios. The objective is to approach the factors leading to the integration of alternative collateral-assets in a sustainable manner; that is, selecting the proper asset which will ensure the enduring performance of a loan. To this end, the applicability and effectiveness of the 'complex proportional assessment' and the 'evaluation of mixed data' methods are investigated, in order to gain insight into the identification and evaluation of critical collateral selection factors. We conclude that under these two classification techniques, the best and the worst collateral choice remains the same, regardless of the order of preference the rest of collaterals might have.

Keywords

Multiple criteria decision analysis; complex proportional assessment; mixed data evaluation; bank lending; loan collateral selection

1. Introduction

Loan collateral[1]-assets are critical complementary bank credit instruments, aiming at supporting and securing the enduring performance[2] of a respective loan facility. It is considered an important mechanism for decreasing credit rationing and credibly signalling borrower quality (Sharpe, 1990; Rajan and Winton, 1995). One could segregate collateral in general of two types (Chan and Kanatas, 1985). Firstly, a borrower can pledge as an inside collateral an asset which is used in the project to be financed. When the borrower defaults, though renegotiation may be possible (Bester, 1994), control of the project and ownership of depreciated assets shift to the lender. Secondly, the borrower can pledge (as outside collateral) assets which are not used in the project. In addition to the high contracting costs associated with collateral, some portion of the debtor's rights to use or transfer ownership of the collateral is generally forfeited (Berger and Udell, 1990) i.e. he may be required to buy fire, theft or damage insurance (payable to the creditor), and sale of the asset may require prior consent of the creditor. In the extreme case, the creditor may take title to and physical possession of the asset for the duration of the debt. Ceteris paribus, collateral decreases the riskiness of a given loan, since it gives the lender a specific claim on an asset without diminishing its general claim against the borrower (Stiglitz and Weiss, 1981).

Moreover, one could divide collateral into personal and physical collateral (Riles, 2011). In the case of personal collateral, the provider is basically liable with his entire fortune. Examples of personal collateral are suretyship, guarantee, letter of support and collateral promise. In the case of physical collateral, the bank receives a specific security interest in certain assets of the borrower or the collateral provider. Examples of physical collateral are real estate prenotation, mortgage, pledge of movable assets (on securities, goods and bills of exchange), security assignment and retention of title.

[1] In this paper, the term "collateral" refers to lender's right to possess the asset used as collateral on borrower's subsequent default or bankruptcy, and might imply that lenders developed either a security interest (i.e., right to liquidate the asset) or a collateral assignment (i.e., possessory right on the asset, based on which a lender can sue for infringement and issue licenses).

[2] There is no single definition of a non-performing loan (NPL). Country definitions differ, and it is recognized that it is possible that what is appropriate in one country may not be so in another. There is, however, some convergence of opinion on this issue. For example, a definition of such loans, summarized in IMF (par. 4.84 - 4.85, 2004) is: 'A loan is non-performing when payments of interest and/or principal are past due by 90 days or more, or interest payments equal to 90 days or more have been capitalized, refinanced, or delayed by agreement, or payments are less than 90 days overdue, but there are other good reasons, such as a debtor filing for bankruptcy, to doubt that payments will be made in full. After a loan is classified as nonperforming, it [and/or any replacement loans(s)] should remain classified as such until written off or payments of interest and/or principal are received on this or subsequent loans that replace the original.' The 90 days overdue criterion is commonly, but not universally, used. The second part of the definition above ensures that NPLs cannot be reclassified as 'performing' simply by replacing them with new loans. Because the 90-day criterion is not universal, any international comparisons relating to NPLs require metadata relating to national practices. We go through the '90 days or more' upper threshold for our investigation.

Especially within banking, collateral traditionally refers to secured lending (also known as asset-based lending). More recently, complex collateralization arrangements are used to secure trade transactions (also known as capital market collateralization). The former often presents unilateral obligations, secured in the form of property, surety, guarantee or other as collateral, whereas the latter often presents bilateral obligations secured by more liquid assets such as cash or securities (Sullivan and Sheffrin, 2003).

As far as the relationship between collateral-value and debt is concerned, Gan (2007) found that firms are less likely to raise debt after an exogenous decrease in the collateral value of their assets. Moreover, Benmelech and Bergman (2009) suggest that collateral redeployability affects cost of debt. Recently, Chaney et al. (2010) explored the effect of shocks to the value of real estate on aggregate investment and found that U.S. corporations invest 6 cents out of each additional dollar of collateral.

In this paper, we have focused our research on shipping sector; that is ships used as collateral-assets in loan agreements. Going back a few decades, in the late 1960's ship-owners broke away from the back-to-back loan system[3] as they found time charters restrictive; they were prevented from taking advantage of the spot market which was performing relatively better (Stopford, 1997). Growing spot market opportunities during that period made bankers believe that the ship itself was sufficient collateral and that no time charter was necessary. Inflation at that time was considered as a benign influence on ships which would protect and enhance ship values throughout their active life. Therefore, the security represented by a first priority mortgage was of exceptionally high quality (Stokes 1997). It was this change in banking strategy that broke the link between supply and demand. Subsequently, during 'convalescence period' in the 90's, bankers began to use both previous weapons, namely mortgaging the financed ship itself and assigning a time charter-party as well, taking the assignment of freight as an additional security (Sloggett, 1998).

In our paper, we propose an integrated and flexible framework to support the selection process of appropriate loan-collaterals, incorporating the standard Multi Criteria Decision Making (MCDM) approach, which we subsequently demonstrate in section 4. We proceed with empirically applying this framework to the case of bank ship finance and ship-collateral

[3] A back-to-back loan denotes a loan in which two companies in different countries borrow offsetting amounts from one another in each other's currency. The purpose of this transaction is to hedge against currency fluctuations. With the advent of currency swaps this type of transaction is no longer used very often (Bakker and Levey, 2012).

selection. The acquisition and financing of a ship vessel by the shipping firm and the bank, respectively, constitute complementary aspects of a critical investment decision that is shaped by the prioritization of multiple quantitative and qualitative criteria (Harwood, 2006). Plausibly, this corporate decision has feedback implications for the loan facility the bank can eventually allocate, as well as for the relevant collateral value the bank is to assess to match undertaken risks. To this end, the primary objective of an MCDM method is to contribute to the identification, evaluation and ranking of fundamental collateral selection criteria that would ensure the enduring performance of a loan.

The empirical approach proposed here is particularly suitable for decisions involving multiple dimensions to be evaluated and due attention to participants' interests to be paid, allowing the decision-maker to negotiate preferences and needs. Hence, the paper applies and evaluates the robustness of an empirical MCDM framework (in the context of bank ship finance), claiming to be the first empirical study towards this direction (according to authors' knowledge). The empirical findings indicate that the choice of the MCDM approach is important; however, the initial structuring of the decision problem that demands for the choice of appropriate criteria and decision options on the underlying collateral-assets remains a most critical issue.

The paper proceeds as follows: in section 2 we give the reader a picture of the importance that previous researchers attached to the asset-based lending. Afterwards, section 3 sets the methodological procedure and analyses relevant data input. Section 4 presents the empirical application and evaluation of two alternative MCDM methods, that is the *complex proportional assessment* (COPRAS) method and the *evaluation of mixed data* (EVAMIX) method, on loan collateral selection. In section 5 we conclude.

2. Theoretical foundations and prior empirical evidence

The important role the collateral plays on credit risk has been searched by several theoretical studies examined from different perspectives. We restrict ourselves here to a discussion of theoretical contributions which are most relevant to our study. Collateral's nature has attracted an increasing amount of attention as an important feature in debt contracting. Academic interest in collateral is not surprising, given its widespread use as an element in commercial loan contracting. Some primitive models have been constructed (Chan and Kanatas 1985; Besanko and Thakor1987; Chan and Thakor, 1987) under the assumption of information asymmetry, where their common prediction is that lower-risk borrowers pledge more collateral. This prediction seems to be at variance with the conventional wisdom in the banking community, which associates the use of collateral with observably risky borrowers

(Bakker and Levey, 2012). In terms of loan application credit analysis, Morsman (1986) argued that commercial lenders assess the riskiness of the prospective borrowers and require the observably risky borrowers to pledge more collateral.

In the data set used by Leeth and Scott (1989) about 60% of firms with commercial bank loans provide collateral as security for the loan agreement. They assume that the age of the firm is a negative proxy for its riskiness as survival in the first years; they argue that it increases the survival chances remarkably in subsequent years. Such proxy is then found to be correlated with collateral. Black et al. (1996), after analyzing a sample of small business loans in the UK, found that small business formation is affected by the amount of collateralizable wealth to a considerable extent. They found that small business formation is affected by the amount of collateralizable wealth to a considerable extent. Coco (2000) supports that the above studies indicate that a convincing theory of debt must consider the role of collateral, explain its massive use and be broadly in accordance with observed regularities about its use.

Many papers in this field could be traced back to various thought-provoking ideas put forth by Berger and Udell (1990; 1995). They have argued that in the USA nearly 70% of all commercial and industrial loans are currently made on a secured basis. Indirect evidence of the widespread use of collateral is that the spread of interest rates charged is remarkably narrow. By performing pooled time-series cross-section analysis on use the Federal Reserve's Survey of 'Terms of Bank Lending' data they examined the empirical relationship between collateral and credit risk while distinguishing among several types of related risk: the risk of the borrower, the risk of the loan, and the risk of the bank. Their evidence suggested that for all three types, there is a positive relationship between collateral and risk: riskier than average firms tend to borrow on a secured basis, the average secured loan tends to be riskier than the average unsecured loan, and banks which make a higher fraction of unsecured loans tend to have riskier portfolios.

Furthermore, Boot and Thakor (1994) modeled an infinitely repeated game between lenders and borrowers where collateralization of loans is explicitly taken into account. They argue that, after providing proof that investment projects have been concluded successfully, the lender will pledge no collateral anymore and will also enjoy improved price conditions. An interesting perspective is given by Kiyotaki and Moore (1997) who explore the macroeconomic implications of collateral dependency. They analyze a dynamic economy in which due to the possibility of diversion, loans must be collateralized and show that procyclical fluctuations in the prices of collateral-assets amplify shocks by diminishing the availability of credit. Carey et al (1998) find that commercial finance companies that specialize in asset-based lending tend to lend to riskier firms than do commercial banks.

In 1998, Harhoff and Korting (1998) presented a study of lending relationships between banks and SMEs in the German economy. They provided a multivariate analysis of the determinants of collateral requirements, loan interest rates, and the availability of external finance. They employed a number of indicators: the duration of the lending relationship, the number of financial institutions the firm is actually borrowing from and a subjective response in which firm managers indicate to which extent they consider their bank relationship as being characterized by mutual trust. Moreover, Klapper (1999) shows that a secured loan (having as collaterals accounts receivable and inventory) allows a lender to make larger loans being permissible on an unsecured basis; thus a risky borrower's investment capital is being maximimised. In addition, she finds that firms using secured loans have less future growth opportunities and are less likely to pay dividends. She also highlights the important role of secured loans in providing liquidity to risky, credit-constrained firms that may not be able to access other venues of external financing.

Lastly, Kose et al. (2003) using a large data set of US public bonds gathered from Securities Data Corporation, document that collateralized debt has higher yield than general debt, after controlling for credit rating. Their results lead to the fact that agency problems[4] between managers and claim holders increase yields on secured debt to a greater extent than on unsecured debt. The yield differential (between secured and unsecured loans after controlling for credit rating) is positive and higher for low credit rating, non-mortgage collateralized assets, longer maturity issues, and with proxies for lower levels of monitoring.

To end with, this paper investigates the validity and usefulness of alternative bank decision techniques that can contribute to different ranking criteria of collateral-assets and their optimal choice (in the sense of performing loans, as mentioned earlier). Past empirical research has proposed a number of MCDM methods and a range of relevant criteria optimization tools[5] (Jee and Kang, 2000; Manshadi et al., 2007; Thakker et al., 2008 inter

[4] As 'agency problem' we refer to a conflict of interest inherent in any relationship where one party is expected to act in another's best interests. The problem is that the agent (in this case, the managers) who is supposed to make the decisions that would best serve the principal (in this case, the claim holders) is naturally motivated by self-interest, and the agent's own best interests may differ from the principal's best interests. The agency problem is also known as the "principal–agent problem."

[5]Optimization means finding an alternative with the most cost effective or highest achievable performance under the given constraints, by maximizing desired factors and minimizing undesired ones (Chong and Zak, 2013). In comparison, maximization means trying to attain the highest or maximum result or outcome without regard to cost or expense. Practice of optimization is restricted by the lack of

alia). The MCDM problems can be classified as standard MCDM and fuzzy MCDM (F-MCDM) ones. In standard MCDM problems, decision-makers take decisions under certainty on the basis of objective criteria. In case of uncertainty, whenever criteria values and weights cannot be definitely assigned, fuzzy theory can contribute to decision making and such problems are known as fuzzy MCDM (Hwang and Yoon, 1981). Furthermore, the MCDM approaches can be broadly categorized into multi-attribute decision-making (MADM) and multi-objective decision-making (MODM) ones (Dey et al., 2012). The former (MADM) approaches deal with the selection of a feasible alternative chosen from a set of alternatives on the basis of their prioritized attributes (criteria). The latter ones (MODM) deal with the selection of an optimal solution from a set of available alternatives according to a set of objectives. Sometimes none of the alternatives satisfies all the objectives; then a satisfactory decision is made instead of an optimal one (see Roy, 1996).

Our contribution to the literature is twofold. First, based on new survey data we provide small-sample descriptive evidence on a ship-collateral classification criteria system, while validating and subsequently weighting such criteria, based on Greek and Cypriot banks which manage shipping portfolios. We have chosen to focus on these two south-eastern European countries due to their worldwide shipping history. Secondly, we implement two MCDM approaches to integrate different ship-collaterals in a sustainable manner, which is the enduring performance of the loans. To our knowledge, such evidence has not been produced prior to this study.

It should be noted that the criteria system presented here is not intended to be exhaustive. Under different assumptions, systems which imply alternative use of attributes regarding the data induced by the researcher, may be developed. This means that various considerations should be made in case of assets (other than ships) i.e. premises, houses, and plots. Our model may be employed by any sector in corporate finance, but this is proposed for further analysis. Moreover, in the case of ship finance, the aspiring researcher can deal with the case-study of other countries having great merchant marine capacity such as Germany, Japan, China, Russia, Norway, Turkey, South Korea, Honk Kong and so on.

An additional research field would be to seek results when intangible assets (patents, trademarks, copyrights, trade secrets, customer lists, domain names and proprietary designs) are incorporated. Besides, during recent decades firms have increasingly invested in

full information, and the lack of time to evaluate what information is available. In computer simulation (modeling) of business problems, optimization is achieved usually by using linear programming techniques of operations research.

intangibles to enhance their uniqueness and competitive advantage (Lev, 2001). However, greater dependence on intangibles distorts firms' ability to raise capital in the credit market, because low redeployability (transfer from one activity to another), higher information asymmetry and uncertain liquidation value inherent in intangibles restrict their effective use as loan collateral (Williamson, 1988; Shleifer and Vishny, 1992; Holthausen and Watts, 2001). A recent study by Amable et al. (2010) seeks the effect on using patents as loan collateral on firms' savings and future innovation growth, suggesting that patent collateralization increases the effect of innovative rents on investments.

3. Methodology and data collection

MCDM is a set of methods which allow the aggregation and consideration of numerous (often conflicting) criteria in order to choose, rank, sort or describe a set of alternatives to aid a decision process (Zopounidis, 1999). MCDM is suitable for the said topic as it is able to address the numerous quantitative and qualitative criteria that affect the sustainable collateral integration, all of which can be incorporated into a single evaluation process. According to Triantaphyllou (2000), there are three steps that all MCDM techniques follow. Firstly, they determine relevant criteria and alternatives; secondly, they attach numerical measures to the relative importance of the criteria and to the impacts of the alternative on these criteria; finally, they process the numerical values to determine a ranking of each alternative. In order to process the numerical values there are various different MCDM methods available, each with their own varying characteristics. Some of the most commonly used methods include the AHP (Saaty, 1980), TOPSIS (Hwang and Yoon, 1981), PROMETHEE (Brans et al., 1986), and ELECTRE (Roy, 1981).

This paper presents two other tools (COPRAS and EVAMIX) that can be used to assess sustainable collateral integration, which is based on a criteria system developed by the authors and validated by professionals in the banking sector. The application of these two MCDM methods will ultimately lead to integration of different collaterals in a sustainable manner; that is selecting the proper asset that will ensure the enduring performance of a loan. It was established that COPRAS and EVAMIX would be suitable methodologies to adopt for the initial pilot assessment of sustainable collateral integration, owing to a number of factors. Firstly, Chatterjee et al. (2011) state that the methods are transparent, simple to use and have a low calculation time in comparison with other MCDM methods, such as AHP and TOPSIS. Therefore, these methods could easily be adopted by any interested parties. Secondly, they can provide a complete ranking of alternatives. Thirdly, they can deal with both quantitative and qualitative criteria within a single assessment. Fourthly, they have the ability to account for both positive (maximizing) and negative (minimizing) evaluation criteria, which can be assessed separately within the evaluation process. Fifthly, they may be used to estimate the priority of alternatives, showing as a percentage the extent to which one alternative is better or worse than other alternatives taken for comparison.

A two stage approach was adopted to develop the sustainable ship-collateral integration criteria system and to validate and subsequently weight such criteria. Initially, a system of criteria defining the ship-collateral assessment was identified via an extensive literature review of bank practices upon valuation and the role of ship-collaterals in loan agreements (Harwood, 2006; Stopford, 2009, Grammenos, 2010, inter alia). We further conducted a field study during May to September 2012 via semi-structured interviews in 3 Greek banks (performing total exposure of USD 6,559 billions of drawn shipping portfolio and total exposure of USD 494 millions of committed but undrawn shipping portfolio, as of April 2012) and 1 Cypriot bank (performing exposure USD 321 millions of drawn shipping portfolio and total exposure of USD 12 millions of committed but undrawn shipping portfolio, as of April 2012). The semi-structured interviews probed bank practitioners on their opinion on the criteria that are important to a sustainable ship-collateral integration; a total of 7 criteria were identified. The full criteria system is presented at the 2^{nd} and 3^{rd} columns of Table 1.

Table 1. Criteria System for sustainable ship-collateral integration and criteria weights

	Criteria	Abbreviation	Weight
1	Ship market value	SMV	0.21
2	Construction shipyard	SY	0.08
3	Light weight tonnage	LWT	0.13
4	Asset Cover Ratio	ACR	0.17
5	Loan-to-value	LTV	0.16
6	Remaining months to loan maturity	MM	0.14
7	Ship age	AS	0.11

Table 1 presents the sustainable ship-collateral integration criteria along with their weights, after searching the literature review and conducting semi-structured interviews during May to September 2012.

Subsequently, the criteria system was validated and weighted via the same survey. All of the criteria differ according to their relative importance to the sustainable ship-collateral integration. Therefore, weighting was introduced in order to reflect the significance of the criteria. The questionnaire survey distributed to above experts leaded to elicit data on the importance of the loan ship-collateral criteria. These experts, basing their answers on their knowledge, experience and perception on sustainable ship-collateral integration, guaranteeing the enduring performance of a loan, ranked the criteria on a scale of importance ranging from 1 to 10; a ranking of 1 meant “not important at all” and a ranking of 10 meant “most important”. This allowed criteria to be validated, or even excluded, from the proposed criteria system. The mean ranking of importance obtained for each criterion was converted into a weight by dividing the sum of mean scores and multiplying by 100. As such, we ensured the total of all weights is 100%. The weights for the criteria obtained via the questionnaire process are displayed at the 4th column in Table 1.

Seven alternative second-hand ships (being candidate securities in an imaginary loan) were selected for comparison purposes. These alternative case study ships were randomly selected amongst the ones we had access to. The alternative ships (being anonymous due to confidentiality reasons) are shown in Table 2.

Table 2. Alternative ships along with their characteristics

	Ship	Type of ship	Tonnage (dwt)	Flag
1	Ship A	bulker	28,300	Malta
2	Ship B	bulker	78,531	Liberia
3	Ship C	bulker	40,000	Malta
4	Ship D	bulker	45,217	Cyprus
5	Ship E	tanker	106,236	Marshall Islands
6	Ship F	bulker	27,908	Malta
7	Ship G	tanker	45,000	Liberia

Table 2 presents the seven alternative second-hand ships picked for our further analysis. They have been randomly chosen from a database provided from 3 Greek banks and a Cypriot one, during May to September 2012.

In more detail, the criteria system is analyzed as follows: the first criterion *SMV* denotes the ship market value based on the semi-annual review of fleet valuation on the banks’ shipping portfolio. For the determination of market value, the bank receives verbal estimates and written documents from one or two approved brokers/surveyors (depending on the circumstances and the peculiarities of the ship or purchase) before the preparation of the term-sheet signed between the lender and the borrower (Harwood, 2006). The significance of this criterion is that the basic security for a shipping loan facility is the ship’s mortgage. The market value of the ship is what actually determines the level of exposure the bank is willing to finance, usually around 70% (Stopford, 1997). The value of a ship is mainly determined by the group that owns the ship, age, quality construction, characteristics, prevailing market conditions, the possibility of successful exploitation, the actual current and future freight rates as well as the type of the charter party (Adland and Koekebakker, 2007).

There are several methodologies of quantifying the ship's market value, but this is out of the scope of this paper. However, regarding the SMV selection we would like to mention a few thoughts. Firstly, the asset value uncertainty (implied by the existence of information costs) is faced by all transactors, whether they are user-owners of an asset, or creditors who obtain an asset by virtue of default. A debtor actually faces a two-part decision when repayment is due: if his reservation value exceeds the amount due, the debt is repaid; otherwise, the debt is repaid only if the market value of the asset exceeds the amount due (Abbott, 2011). Given uncertainty about the future value of the asset, default will occur on average only when the market value of the asset is relatively low, implying that the creditor's expected recovery from sale of the collateral will be biased downward relative to the expected price of the asset.

The second criterion *SY* signifies the shipyard where the ship has been constructed, taking into account both the country of construction and the shipyard itself. This is founded on the value-added theory, triggered when the ship's hull, paints, machines, cranes etc. are being built in a state-of-the-art shipyard (European Community, 2003). The third criterion *LWT* symbolizes the lightweight tonnage of each ship, necessary for an estimation of the ship's scrap value. Lightweight tonnage is best described as the weight of the ship when it was built in the shipyard including all framing, machinery, decking, etc. However, lightweight tonnage does not include the weight of any consumable such as fuel, water, oil, or supplies (Stopford, 1997).

The fourth criterion *ACR* (asset cover ratio) indicates the sum of ship market value plus loan cash-collateral plus premises market value divided to loan outstanding amount plus loan overdue payments[6]. The fifth criterion *LTV*[7] (Loan-to-value) is a gearing ratio designating the reverse ACR ratio; it is the ratio of the size of the loan to the estimated asset (ship) value. LTV tells the lender if potential losses due to non-payment may be recouped by selling the ship (Jokivuolle and Peura, 2003).

[6] ACR appears as 'Hull-to-Debt ratio' (HDR) into shipping business (Grammenos, 2010).

[7] Remember that the LTV ratio was the actual credit risk management tool of securitization procedure, widely used by banks prior to the US housing bubble burst in 2007. When mortgages were securitized, the only information received about the mortgages was the LTV ratio and the borrower's preliminary credit score (of doubtful quality). The most important thing for the lender was whether the mortgage could be sold to others and not whether the credit strategy complies with the bank's (or national or international) regulatory capital requirements (see Keys et al., (2010) for a link between securitization and the lax screening of mortgages). Additionally, some useful points that Benjamin (1978) resulted in are: firstly, the greater the rate of appreciation of the asset, the lower will be the interest rate charged for any given ratio of LTV. Secondly, the maximum allowable loan (as a fraction of the current market value of the asset) will be a non-decreasing function of the rate of appreciation of the asset; fourthly given the ratio of LTV, the default rate on debts will be a decreasing function of the rate of appreciation of the value of the asset. Finally, given the LTV, the losses incurred by creditors on defaulted obligations will be lower, the greater the rate of appreciation of the collateral asset.

The sixth criterion *MM* means the amount in months remaining until the final maturity of the loan (without taking into account any possible refinancing strategies that would turn this parameter non-estimable), whereas the seventh criterion *AS* stands for the age of ships as in May 2012, during which we conducted our research.

4. Empirical Application and evaluation of COPRAS and EVAMIX techniques

Guitouni and Martel (1998) argued that despite the large quantity of MCDM methods available, no single method is considered the most suitable for all types of decision-making situation. It has also been acknowledged by Hajkowicz and Higgins (2008) that several methods can be potentially valid for a particular decision making situation; there is not always an overwhelming reason to adopt one technique over another. It seems that one of the most important principles in selecting a MCDM method is its compatibility with the problem's objective (Venkata-Rao, 2013). The problem proposed in this study is the assessment of integration of different collaterals in a sustainable manner; that is selecting the proper asset that will ensure the enduring performance of a loan. To determine this, a ranking of alternatives needs to be identified; therefore, the ultimate objective of this problem is to rank alternatives.

Consequently, a MCDM method that has the ability to provide a complete ranking of alternatives is required. The method must have the ability to handle criteria of both positive and negative influence and those of a quantitative and qualitative nature. The ease of use and understanding of the MCDM technique is important so that any interested parties can easily adopt the proposed method. In this paper, an attempt is made to explore the applicability and capability of two MCDM methods, i.e. (i) *complex proportional assessment* (COPRAS), and (ii) *evaluation of mixed data* (EVAMIX).

4.1 Complex Proportional Assessment Method (COPRAS)

The COPRAS method assumes direct and proportional dependence of significance and priority of investigated alternatives on a system of criteria (Zavadskas et al., 2004). The significance of the comparative alternatives is determined on the basis of describing positive and negative characteristics of the alternatives. The method ultimately estimates the priority order of the alternatives.

The empirical implementation of COPRAS consists of the following steps (Zavadskas et al., 2004; Kaklauskas et al., 2007; Venkata-Rao, 2013 :

Step 1:

We pick the set of criteria for the integration of different collaterals in a sustainable manner, as collected and classified from the survey. We proceed to the construction of the decision-making matrix X; this matrix evaluates and prioritizes the list of options we have and actually establishes a list of criteria:

$$X = \lfloor X_{ij} \rfloor_{\mu x \nu} = \begin{bmatrix} x_{11} & \dots & \dots & x_{1\nu} \\ x_{21} & \dots & \dots & x_{2\nu} \\ \dots & \dots & \dots & \dots \\ x_{\mu 1} & x_{\mu 2} & \dots & x_{\mu\nu} \end{bmatrix} \tag{1}$$

where x_{ij} is the value of *i*th ship-collateral assessment criterion on *j*th alternative ship, μ is the number of criteria and v is the number of alternatives compared.

Step 2:

We normalize the decision-making matrix X, namely translating data measured with different units (such as points, ratio, percentage) into weighted dimensionless variables, allowing this way their direct comparison.

$$P = \lfloor \rho_{ij} \rfloor_{\mu x \nu} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}} \tag{2}$$

Step 3:

We determine the weighted normalized decision matrix, Δ.

$$\Delta = \lfloor d_{ij} \rfloor_{\mu x \nu} = \rho_{ij} w_i \tag{3}$$

where ρ_{ij} is the normalized value of *i*th criterion on *j*th alternative found in step 2 and w_i is the weight of *i*th criterion. With this transformation, the sum of dimensionless weighted normalized values d_{ij} of each criterion x_i always equals the weight w_i of this criterion, namely:

$$\sum_{j=1}^{\nu} d_{ij} = w_i \tag{4}$$

In other words, the weight w_i of the investigated criterion is proportionally distributed among all alternatives, according to their weighted normalized value, d_{ij}. Weighted normalized values are presented in Table 3.

Table 3. Weighted normalized decision matrix

	Ship	SMV	SY	LWT	ACR	LTV	MM	AS
1	Ship A	0.0234	0.0188	0.0229	0.0172	0.0331	0.0277	0.0117
2	Ship B	0.0222	0.0214	0.0116	0.0134	0.0155	0.0162	0.0192
3	Ship C	0.0036	0.0130	0.0192	0.0291	0.0118	0.0178	0.0114
4	Ship D	0.0266	0.0212	0.0125	0.0011	0.0217	0.0017	0.0091
5	Ship E	0.0038	0.0121	0.0261	0.0219	0.0129	0.0152	0.0266
6	Ship F	0.0273	0.0028	0.0087	0.0099	0.0027	0.0156	0.0087
7	Ship G	0.0020	0.0256	0.0121	0.0019	0.0115	0.0400	0.0281

Table 3 presents the weighted normalized values, whereas the weight w_i of the investigated criterion is proportionally distributed among all the alternatives, according to their weighted normalized value, d_{ij}. SMV stands for ship market value, SY for construction shipyard, LWT for light weight tonnage, ACR for asset cover ratio, LTV for loan-to-value, MM for remaining months to loan maturity and AS is the ship's age. For convenience, we have installed positive-beneficial criteria at the left of the dashed line and negative-non beneficial criteria, at the right side (the terms explained in step 4).

Step 4:

The sums of weighted normalized criteria describing the *j*th alternative are calculated. The alternatives are described by positive-beneficial (maximizing) criteria S_{+j} (Eq.5) and negative-non beneficial (minimizing) criteria S_{-j} (Eq.6). Higher the positive (maximizing) values are, such as 'shipyard where ship has been constructed' better satisfied is the sustainable ship-collateral integration. Lower the negative (minimizing) values are, such as 'number of months remaining to loan maturity' better satisfied is the sustainable ship-collateral integration. Sums are calculated according to formulas:

$$S_{+j} = \sum_{i=1}^{\mu} d_{+ij} \quad (5)$$

$$S_{-j} = \sum_{i=1}^{\mu} d_{-ij} \quad (6)$$

On the basis of Eqs. 5 and 6, the sums of the weighted normalized values are calculated for both the beneficial (S_{+i}) and the non beneficial criteria (S_{-i}), as indicated in Table 4.

Table 4. Sums of the weighted normalized values

	Ship	S_{+i}	Value	S_{-i}	Value
1	Ship A	S_{+1}	0.0823	S_{-1}	0.0725
2	Ship B	S_{+2}	0.0686	S_{-2}	0.0509
3	Ship C	S_{+3}	0.0649	S_{-3}	0.0410
4	Ship D	S_{+4}	0.0614	S_{-4}	0.0325
5	Ship E	S_{+5}	0.0639	S_{-5}	0.0547
6	Ship F	S_{+6}	0.0487	S_{-6}	0.0270
7	Ship G	S_{+7}	0.0416	S_{-7}	0.0796

Table 4 presents the sum of the weighted normalized values for every alternative ship. The weightd normalized values are discriminated as positive-beneficial (maximizing) criteria S_{+j} and negative-non beneficial (minimizing) criteria S_{-j}.

Step 5:

We determine the prioritization Q_j of alternative collaterals. The greater the value Q_j the higher the priority (significance) of the alternative. The significance (priority) of the comparative alternatives is determined on the basis of describing positive (+) and negative (-) qualities that characterize the alternative ships. The relative significance Q_j of each alternative ship is determined according to:

$$Q_j = S_{+j} + \frac{S_{-\min}\sum_{j=1}^{v} S_{-j}}{S_{-j}\sum_{j=1}^{v} S_{-\min}/S_{-j}} \tag{7}$$

where S_{-min} is the minimum value of S_{-j}. The first term of Q_j increases for higher positive criteria S_{+j}, whilst the second term of Q_j increases with lower negative criteria S_{-j}. Thus a higher value of Q_j corresponds to more sustainable collateral integration.

Step 6:

We determine the alternative that best satisfies the sustainable ship-collateral integration, by calculating its degree of utility[8], which is Q_j/Q_{max}. The degree of each ship utility is determined by comparing each alternative with the most efficient one. The ship that best satisfies the sustainable ship-collateral integration is expressed by the highest degree of utility N_j equaling 100%. The degrees of utility will range from 0% to 100%, between the worst and best alternative. The utility degree N_j of each alternative is determined according to the following formula:

[8] With the increase/decrease of the priority of each alternative, its degree of utility increases/decreases.

$$N_j = \left[\frac{Q_j}{Q_{max}} \right] \times 100\% \qquad (8)$$

The concluding results of step 6 of the COPRAS assessment method are displayed in Table 5.

Table 5. Relative significance, utility degrees and final rank of the alternative ships

	Ship	Q_j	N_j	Rank
1	Ship A	0.1548	5.2951	7
2	Ship B	0.3678	12.5799	6
3	Ship C	0.7241	24.7689	5
4	Ship D	1.2543	42.9053	3
5	Ship E	1.2212	41.7716	4
6	Ship F	2.9234	100	1
7	Ship G	1.6535	56.5601	2

Table 5 presents the relative significance Q_j, utility degrees N_j and the final rank of each alternative. As shown in the table, the rank that better serves the integration of different ship-collaterals in a sustainable manner is firstly Ship F, then Ship G, Ship D, Ship E, Ship C, Ship B and finally Ship A.

Using the MCDM method COPRAS, an initial assessment of sustainable collateral integration was conducted. We compared seven alternative assets being collaterals in an imaginary loan, based on seven weighted decision criteria. A ranking of the priorities (significances) of the assets was compiled (Table 5): priority 1 = Ship F, priority 2 = Ship G, priority 3 = Ship D, priority 4 = Ship E, priority 5 = Ship C, priority 6 = Ship B and priority 7 = Ship A. Therefore, the ship that best satisfies sustainable ship-collateral integration is Ship F. Ship A was determined as the worst performing ship, meaning that in case the bank uses Ship A as collateral for the under study shipping loan, it shall guarantee less on the loan performance, than the other assets.

The above reasoning tell us that identifying appropriate assets for enduring loan performance would assist in ensuring high quality of loans, leading to lower loan provisions. Furthermore, the tool could support bankers in making decisions on asset financing selection, identifying collateral assets appropriate to both lender and borrowers' needs and preferences for criteria.

4.2 Evaluation of mixed data (EVAMIX)

An approach to tackling mixed information is the EVAMIX method (Voogd, 1982, 1983). EVAMIX involves the construction of two measures: one dealing only with the qualitative (ordinal) criterion score and the other with the quantitative (cardinal) criterion scores. From a procedural point of view, in order to serve the integration of different collaterals in a sustainable manner, this approach consists of six steps (Nijkamp et al. 1990; Martel and Matarazzo, 2005; Hajkowicz and Higgins, 2008; Munda, 2008; Chatterjee et al., 2011):

Step 1:

We make a distinction between qualitative (ordinal) and quantitative (cardinal) criteria and proceed to the construction of a decision-making matrix E, which is a μ-by-ν matrix, characterized by μ decision criteria and ν alternative ships. Its components are qualitative or quantitative entries, which express by rows the performance of each alternative with respect to a certain criterion. Given a set of decision criteria *j* (j = 1, 2, … μ) and a finite set of alternatives *i* (i = 1, 2, …, ν), the decision-making matrix E will be characterized by its qualitative and quantitative components e_{ji}:

$$E = \lfloor E_{ij} \rfloor_{\mu x \nu} = \begin{bmatrix} e_{11} & \cdots & \cdots & e_{1\nu} \\ e_{21} & \cdots & \cdots & e_{2\nu} \\ \cdots & \cdots & \cdots & \cdots \\ e_{\mu 1} & e_{\mu 2} & \cdots & e_{\mu\nu} \end{bmatrix}$$

In our case, we consider as quantitative criteria the (MV), (LWT), (ACR), (LTV), (MM), (AS) and as qualitative only the (SY) criterion.

Step 2:

For positive-beneficial (maximizing) criteria, we normalize the decision matrix using the following equation:

$$\rho_{ij} = \left[\frac{e_{ij} - {}_{\min}(e_{ij})}{{}_{\max}(e_{ij}) - {}_{\min}(e_{ij})} \right] \quad \text{(i=1,2,…,μ ; j=1,2,...,ν)} \tag{9}$$

For negative-non beneficial (minimising) criteria the equation above can be written as:

$$\rho_{ij} = \left[\frac{{}_{\max}(e_{ij}) - e_{ij}}{{}_{\max}(e_{ij}) - {}_{\min}(e_{ij})} \right] \tag{10}$$

The decision-making matrix E is normalized using Eqs. (9) and (10) respectively for positive and negative criteria. This normalized matrix is shown in Table 6.

Table 6. Normalized Decision-making Matrix

	Ship	SMV	SY	LWT	ACR	LTV	MM	AS
1	Ship A	0.0023	0.0288	0.1884	0.3423	0.0036	0	0
2	Ship B	0.0032	0.8843	0	0.9787	0.3998	1	0.2498
3	Ship C	1	0.9382	0.2325	0.0938	0.2883	0	0.0956
4	Ship D	0.6278	0	0.0048	0.8826	0.8843	0.5520	0
5	Ship E	0.8912	0.3929	0.0433	1	0	0.8845	0
6	Ship F	1	1	0.7436	0.8892	0.7262	0.8834	0.6612
7	Ship G	0.2138	0.7746	0.8830	0.2663	0.9466	0.5299	0.4436

Table 6 presents the values of normalized qualitative (ordinal) and quantitative (cardinal) criteria. SMV stands for ship market value, SY for construction shipyard, LWT for light weight tonnage, ACR for asset cover ratio, LTV for loan-to-value, MM for remaining months to loan maturity and AS is the ship's age. For convenience, we have isolated the only qualitative (cardinal) criterion SY with a dashed line.

Step 3:

The set of criteria *j* is divided into two subsets, denoted O and C, where O is the set of the qualitative (ordinal) criteria and C the set of quantitative (cardinal) criteria, obtaining two distinct decision matrices: E_O (qualitative criteria/alternatives) and E_C (quantitative criteria/alternatives). This way the differences among alternatives can be expressed by means of two dominance scores: the first one based on qualitative criteria and the second one based on quantitative criteria. We determine the dominance score of each alternative pair (*i,i'*) by:

$$\alpha_{ii'} = \left[\sum_{j \ni E_O}^{\mu} \{w_j \operatorname{sgn}(\rho_{ij} - \rho_{i'j})\}^c\right]^{1/c} \qquad c=1,3,5,... \tag{11}$$

and

$$\gamma_{ii'} = \left[\sum_{j \ni E_C}^{\mu} \{w_j \operatorname{sgn}(\rho_{ij} - \rho_{i'j})\}^c\right]^{1/c} \tag{12}$$

where

$$\operatorname{sgn}(\rho_{ij} - \rho_{i'j}) = \begin{cases} +1 & \text{if } \rho_{ij} > \rho_{i'j} \\ 0 & \text{if } \rho_{ij} = \rho_{i'j} \\ -1 & \text{if } \rho_{ij} < \rho_{i'j} \end{cases}$$

where *c* is the scaling parameter[9] which controls the influences of differences arising from minor criteria, for which any arbitrary positive odd number may be chosen; the larger *c* is, the lesser the influences of differences on minor criteria (Munda, 2008); $\alpha_{ii'}$ and $\gamma_{ii'}$ are the dominance scores for alternative ship pairs (*i,i'*) regarding to qualitative and quantitative criteria respectively; the *sgn* sign function or 'signum function' is an odd mathematical

[9] In probability theory and statistics, a scale parameter is a special kind of numerical parameter of a parametric family of probability distributions. The larger the scale parameter, the more spread out the distribution (Venkata-Rao, R., 2013).

function that extracts the sign of a real number and is -1 for a negative number, 0 for the number zero, or +1 for a positive number. The dominance score of the alternative ship pairs (*i,i'*) is presented in Table 7.

Table 7. Dominance score of alternative ship pairs

Ship pair	$\alpha_{ii'}$	$\gamma_{ii'}$	Ship pair	$\alpha_{ii'}$	$\gamma_{ii'}$	Ship pair	$\alpha_{ii'}$	$\gamma_{ii'}$
(1,2)	-0.18	-0.11	(3,4)	0.18	-0.12	(5,6)	-0.18	0.14
(1,3)	-0.18	-0.11	(3,5)	-0.18	-0.11	(5,7)	-0.18	-0.11
(1,4)	-0.18	-0.11	(3,6)	-0.18	-0.23	(6,1)	0.18	0.11
(1,5)	-0.18	0.13	(3,7)	-0.18	0.14	(6,2)	0.18	0.34
(1,6)	-0.18	-0.11	(4,1)	0.18	0.11	(6,3)	0.18	0.23
(1,7)	-0.18	-0.11	(4,2)	-0.18	-0.16	(6,4)	0.18	0.11
(2,1)	0.18	0.11	(4,3)	-0.18	0.12	(6,5)	0.18	-0.14
(2,3)	-0.18	0.11	(4,5)	0.18	-0.11	(6,7)	0.18	0.11
(2,4)	0.18	0.16	(4,6)	-0.18	-0.11	(7,1)	0.18	0.11
(2,5)	0.18	0.11	(4,7)	0.18	0.12	(7,2)	-0.18	0.11
(2,6)	-0.18	-0.34	(5,1)	0.18	-0.13	(7,3)	0.18	-0.14
(2,7)	0.18	-0.11	(5,2)	-0.18	-0.11	(7,4)	-0.18	-0.12
(3,1)	0.18	0.11	(5,3)	0.18	0.11	(7,5)	0.18	0.11
(3,2)	0.18	-0.11	(5,4)	-0.18	0.11	(7,6)	-0.18	-0.11

Table 7 presents the dominance score of each alternative ship pair (*i,i'*). $\alpha_{ii'}$ and $\gamma_{ii'}$ are the dominance scores for alternative ship pair (*i,i'*) regarding to qualitative and quantitative criteria respectively. While calculating the dominance scores, the value of *c* is taken as 1 for our convenience; when *c* is small then the distribution is more concentrated (Chatterjee et al., 2011).

Step 4:

We calculate the normalised dominance scores. One approach to obtain normalised qualitative and quantitative dominance scores ($\delta_{ii'}$, $\sigma_{ii'}$) is given in Martel and Matarazzo (2005), and is called the 'additive interval approach'[10]. This techniques is applied in this paper by calculating the formulae

$$\delta_{ii'} = \frac{\alpha_{ii'} - \alpha^-}{\alpha^+ - \alpha^-} \tag{13}$$

where δ_i is the normalized qualitative dominance score; α^+ and α^- are the highest and lowest qualitative dominance scores respectively, for the alternative pairs (*i,i'*). Respectively we compute the formulae

$$\sigma_{ii'} = \frac{\gamma_{ii'} - \gamma^-}{\gamma^+ - \gamma^-} \tag{14}$$

where σ_i is the normalized quantitative dominance score; γ^+ and γ^- are the highest and lowest quantitative dominance scores respectively, for the alternative pairs (*i,i'*).

[10] See Nijkamp et al (1990) for two other techniques called 'subtracted summation technique' and 'subtracted shifted interval technique'.

Based on the additive interval technique, the normalized dominance scores for all the pairs of alternative ships are determined using Eqs. (13) and (14) for the qualitative and quantitative criteria respectively, and are given in Table 8.

Table 8. Normalized dominance score of each alternative ship pair

Ship pair	$\delta_{ii'}$	$\sigma_{ii'}$	Ship pair	$\delta_{ii'}$	$\sigma_{ii'}$	Ship pair	$\delta_{ii'}$	$\sigma_{ii'}$
(1,2)	0	0.3382	(3,4)	1	0.3235	(5,6)	0	0.7059
(1,3)	0	0.3382	(3,5)	0	0.3382	(5,7)	0	0.3382
(1,4)	0	0.3382	(3,6)	0	0.1618	(6,1)	1	0.6618
(1,5)	0	0.6912	(3,7)	0	0.7059	(6,2)	1	1.0000
(1,6)	0	0.3382	(4,1)	1	0.6618	(6,3)	1	0.8382
(1,7)	0	0.3382	(4,2)	0	0.2647	(6,4)	1	0.6618
(2,1)	1	0.6618	(4,3)	0	0.6765	(6,5)	1	0.2941
(2,3)	0	0.6618	(4,5)	1	0.3382	(6,7)	1	0.6618
(2,4)	1	0.7353	(4,6)	0	0.3382	(7,1)	1	0.6618
(2,5)	1	0.6618	(4,7)	1	0.6765	(7,2)	0	0.6618
(2,6)	0	0.0000	(5,1)	1	0.3088	(7,3)	1	0.2941
(2,7)	1	0.3382	(5,2)	0	0.3382	(7,4)	0	0.3235
(3,1)	1	0.6618	(5,3)	1	0.6618	(7,5)	1	0.6618
(3,2)	1	0.3382	(5,4)	0	0.6618	(7,6)	0	0.3382

Table 8 presents the normalised dominance score of each alternative ship pair (*i,i'*). $\delta_{ii'}$ and $\sigma_{ii'}$ denote the normalised dominance scores for alternative ship pair (*i,i'*) regarding to qualitative and quantitative criteria respectively.

Step 5:

We calculate the overall dominance scores. The overall dominance score ($\Delta_{ii'}$) for each pair of alternatives (*i,i'*) is calculated by means of Eq. 15 and is giving the degree in which solution *i* dominates solution *i'*.

$$\Delta_{ii'} = W_O\delta_{ii'} + W_C\sigma_{ii'} \tag{15}$$

where W_O is the sum of the weights for the qualitative (ordinal) criteria ($W_O = \Sigma_{j\epsilon O}W_j$) and W_C is the sum of the weights for the quantitative (cardinal) criteria ($W_C = \Sigma_{j\epsilon C}W_j$). The overall dominance scores for all pairs of alternative ships are shown in Table 9.

Table 9. Overall dominance scores

Ship pair	$\Delta_{ii'}$	Ship pair	$\Delta_{ii'}$	Ship pair	$\Delta_{ii'}$
(1,2)	0.3112	(3,4)	0.3776	(5,6)	0.6494
(1,3)	0.3112	(3,5)	0.3112	(5,7)	0.3112
(1,4)	0.3112	(3,6)	0.1488	(6,1)	0.6888
(1,5)	0.6359	(3,7)	0.6494	(6,2)	1.0000
(1,6)	0.3112	(4,1)	0.6888	(6,3)	0.8512
(1,7)	0.3112	(4,2)	0.2435	(6,4)	0.6888
(2,1)	0.6888	(4,3)	0.6224	(6,5)	0.3506
(2,3)	0.6088	(4,5)	0.3912	(6,7)	0.6888
(2,4)	0.7565	(4,6)	0.3112	(7,1)	0.6888
(2,5)	0.6888	(4,7)	0.7024	(7,2)	0.6088
(2,6)	0.0000	(5,1)	0.3641	(7,3)	0.3506
(2,7)	0.3912	(5,2)	0.3112	(7,4)	0.2976
(3,1)	0.6888	(5,3)	0.6888	(7,5)	0.6888
(3,2)	0.3912	(5,4)	0.6088	(7,6)	0.3112

Table 9 presents the overall dominance scores ($\Delta_{ii'}$) for each pair of ship alternatives (*i,i'*).

Step 6:

We calculate the final priority scores. The final priority score Θ_i for *i*th ship alternative is calculated by[11] Eq. 16 and is giving the final priority of the alternative ships

$$\Theta_i = \sum_{i'} \left(\frac{\Delta_{i'i}}{\Delta_{ii'}} \right)^{-1} \tag{16}$$

Higher the priority score better is the performance of the alternative. The priority score for each ship alternative, calculated using Eq. 16, is shown in Table 10.

[11] If the three different approaches (the one used here plus the ones stated in footnote 4) are simultaneously used or if more than one technique are used for calculating the normalized dominance score for *i*th alternative with respect to other alternatives, then a normalized average appraisal score ($\Theta_{\alpha i}$) for *i*th alternative can be obtained as follows (Hajkowicz and Higgins, 2008)

$$\Theta_{\alpha i} = \sum_{t=1}^{p} \left(\frac{\Theta_{ti} - \Theta_{ti\min}}{\Theta_{ti\max} - \Theta_{ti\min}} \right)$$

where Θ_{ti} is the appraisal score of *i*th alternative for each technique, and Θ_{timin} and Θ_{timax} are the lowest and the highest appraisal scores for each technique respectively. Such methodology results in a complete ranking of the alternatives based on the normalized average appraisal score value and the best alternative is the one having the highest average appraisal score.

Table 10. Priority score of alternative ships

Ship	Θ_i	Rank
Ship A	0.5755	7
Ship B	1.0936	2
Ship C	0.7478	6
Ship D	0.9733	3
Ship E	0.9566	5
Ship F	2.4648	1
Ship G	0.9645	4

Table 10 presents the priority score Θ_i for alternative ships. Last column demonstrates the final ranking of the ships. Ship F is the alternative, which serves the best way the integration of different ship-collaterals in a sustainable manner.

Using the MCDM method EVAMIX, an initial assessment of sustainable collateral integration was conducted. Our study, based on 7 decision criteria, compared 7 alternative collateral assets. A ranking of the priorities (significances) of the assets has been compiled (Table 10): priority 1 = Ship F, priority 2 = Ship B, priority 3 = Ship D, priority 4 = Ship G, priority 5 = Ship E, priority 6 = Ship C and priority 7 = Ship A. Therefore, the ship that best satisfies the sustainable ship-collateral integration is Ship F. Ship A was determined as the worst performing ship, meaning that in case the bank uses Ship A as the collateral asset for the under study loan, this shall guarantee less on the loan sustainable performance, than the other ships.

By using either COPRAS or EVAMIX methods to test the integration of different collaterals in a manner that guarantees the sustainable performance of a loan, it is observed that the first and last priority is given to the same alternative (Ship F and Ship A respectively), regardless to what the ranking of the rest of the ships is (F-G-D-E-C-B-A & F-B-D-G-E-C-A respectively).

5. Conclusions

Much of the literature of collateral (particularly the empirical literature) has focused on the relationship between collateral and the riskiness of the underlying firm, along with how and why yields (net of credit rating) vary with collateral and loan characteristics. Little is known about the classification of collaterals via a criteria system, searching for the optimum one which shall lead to the enduring performance of a loan. This article fills this gap in the literature along both theoretical and empirical dimensions, using the MCDM analysis.

Multiple Criteria Decision Making (MCDM) is the process of selecting an optimal solution from a set of available alternatives for satisfying a set of objectives. MCDM is applied to analyse complex real life problems with various criteria for possible selection of the best/suitable alternative. From the last decade MCDM has grown leaps and bounds in business sectors, industries, agriculture, rural and urban area development, sustainable development, forestry management, finance, defense and as well as in sports.

In this paper we search how two MCDM methods, the *complex proportional assessment* (COPRAS) and the *evaluation of mixed data* (EVAMIX) can be applied to identify/evaluate the criteria leading to the integration of different collaterals in a sustainable manner; that is selecting the proper asset that will ensure the enduring performance of a loan. We show that their results differ, only at the ranking between the best and the worst alternative, under different classification techniques. This has implications on deciding where to focus effort when applying a MCDM method. Often it is far more important to focus effort on structuring the decision problem (involving identifying decision options, criteria and criteria weights) than trying to decide which MCDM technique to apply.

To our knowledge, ours is the first study to empirically examine the nature of sustainable ship-collateral integration criteria system and to validate and subsequently weight such criteria. Hence, the empirical results are of interest in their own right and raise a number of questions for future research.

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Acknowledgements

We would like to thank two anonymous colleagues from Department of Financial and Management Engineering, Business School, University of Aegean for their supportive suggestions. We are grateful to the various shipping bank officers for helpful comments that improved the content and exposition of the paper, as well as the shipping firms which corresponded to the survey conducted and presented here.