Risk Analysis, Practice, and Considerations in Capital Budgeting: Evidence from the Field for the Bio-based Industry

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This study aims to examine how organizations in the bio-based industry perceive risks and perform risk analysis within the capital investment decision-making process. More specifically, this study aims to assess sources of uncertainty commonly considered, identify tools and methods used for risk assessment, and understand how risk analysis is considered in capital budgeting. Eighty-six respondents were electronically surveyed on practices for capital investment risk analysis, including C-suite and upper management from different organization sizes and segments in the bio-based industry. It was found that some forms of risk analysis are utilized either in project assessment and/or for decision making by most respondents; however, qualitative and deterministic assessment practices dominate over probabilistic methods. In addition, risk assessment is most commonly performed in the later stages of a project, with less than 50% of adoption at the earlier stages. Overall, the main sources of uncertainties considered when performing risk assessment are financial, market and sales, and technology, with competition being considered mostly by upper management levels. Additionally, consistent with previous studies in other industry sectors, Internal Rate of Return, Return on Investment, and Net Present Value are the preferred financial indicators used to evaluate capital investments.

Keywords: Financial risk analysis; Capital budgeting; Investment assessment; Project evaluation; Bioeconomy; Bio-based industry; Biomaterials

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INTRODUCTION

The bio-based industry is defined here as the collection of companies that use predominately renewable feedstocks, such as bio-based fibers, biomaterials, and biochemicals, in their conversion processes. Agricultural activities are excluded from this category. Successful business examples within the bio-based sector include sugar cane mills in Brazil (producing sugar, ethanol, and power), corn ethanol plants in the U.S. (producing ethanol, animal feed, and numerous byproducts), pulp and paper facilities worldwide, wood pellet facilities rising in North America, and the emerging bio-based plastics and bio-based solvents manufacturing in South America (Holladay *et al.* 2007; Golden and Handfield 2014; Baker 2016; Schaubach 2017; Thrän *et al.* 2017; Braskem 2020). Consumer interest in sustainable products has considerably increased in recent

years, opening an unprecedented opportunity for the bio-based sector to further develop and satisfy the emerging needs of society. The so-called new-bio-based development is emerging mostly *via* small- and medium-enterprises, which are striving for success among the myriad of challenges inherent to new businesses, along with uncertainties specific to the bio-based industry. Factors such as continuous development of new technologies (*i.e.*, technologies at different readiness levels) (Gonzalez *et al.* 2011a,b), uncertain product prices (de Assis *et al.* 2017a,b, 2018), and geopolitical dynamics (Goh *et al.* 2013; Singh *et al.* 2016), in combination with unique uncertainties found in the bio-based sector, such as variability in feedstock composition (Treasure *et al.* 2014) and feedstock availability (Gonzalez *et al.* 2011c), add more complexity to the already intricate investment decision-making environment of the bio-based sector. In order to reduce the chances of project failure and maximize value, it is crucial to incorporate risk assessment into the decision-making processes (Brauers 1986; Curtis and Carey 2012). The present study aimed to investigate how risk analysis practices are used in organizations within the bio-based industry, and how risk analysis outcomes are considered in the capital budgeting decision-making process. To fulfill these goals, this study conducted a survey with decision-makers from different organizations in the bio-based sector.

In this study, 'risk' is defined as a random event that negatively affects a company's goal. Risk analysis (or risk assessment) is a methodology used to estimate the sources and the consequences of a risk (de Assis *et al.* 2017a). The authors hope that the findings help researchers and organizations from public and private sectors to understand how risk analysis is perceived and used for decision making in the bio-based sector, opening space to evaluate and improve practices, aiming for more comprehensive and efficient risk assessment and management.

Previous academic studies have investigated capital budgeting practices in organizations across different regions (Schall *et al.* 1978; Schall and Sundem 1980; Arnold and Hatzopoulos 2003; Bennouna *et al.* 2010), organization levels of consolidation (Oblak and Helm 1980; Shao and Shao 1996), and over defined periods in history (Pike 1996). In said studies, the use of risk analysis and assessment techniques have been briefly explored because it was not the main emphasis of the studies. In contrast, other studies have focused on risk analysis in capital budgeting and corporate investments, and often investigated how organizations measure, handle, and incorporate risks associated with project returns (Ho and Pike 1991). Additionally, some studies have investigated how the use of sophisticated techniques to handle risk have influenced the number of capital investment projects approved (Ho and Pike 1992) and evaluated the influence of organizational culture in adopting risk analysis practices (Ho and Pike 1998). It is worth noting that these studies define risk as the impossibility of the decision-maker to estimate outcomes related to their investment decisions, and mainly consider a financial perspective of risk (the sampled population was composed only by financial executives and directors). Outside of academia, consulting organizations often release results from surveys on risk assessment practices for different industry sectors (*e.g.*, manufacturing and banking) (Miller *et al.* 2015; Pkhakadze 2016), examining trends in enterprise risk management (ERM) application (RIMS and Advisen Ltd. 2013) and evaluating how organizations respond to external uncertainties (Culp 2013). Findings from previous works confirm that risk assessment practice and its perceived importance are increasing within organizations.

Studies collecting evidence from the field on methods, sources of risks, and the use of risk assessment in decision-making for the bio-based industry are fairly limited; indeed, relatively few studies have focused on understanding risk assessment practices in the pulp

and paper, forestry, lumber, and timberland sectors (Bailes *et al.* 1978; Cubbage and Redmond 1985; Hogaboam and Shook 2004; Acuña *et al.* 2015). These studies, which were conducted at least 15 years ago, have focused on capital budgeting practices, with a superficial assessment of risk analysis procedures. Topics analyzed and discussed comprised the perception of risky investments and the techniques used to adjust project risk from a financial perspective. The novelty of this assessment resides in i) the use of risk analysis in capital budgeting for the bio-based sector; ii) the broad variety of business segments selected within the bio-based industry (such as pulp and paper, personal care, consulting, chemicals, fuels, biomaterials, and forest management); iii) the detailed investigation of risk assessment practices (*e.g.*, existence of a dedicated department within the organization, use of risk analysis in different project stages, the use of qualitative *vs.* deterministic assessment procedures, as well as the tools used); and iv) the evaluation of important aspects currently adopted by the industry that were not covered in previous studies (such as sources of uncertainty considered and the perceived benefits of using risk analysis in decision making). This paper aims to provide a more comprehensive view on the use of risk analysis in areas other than finance, contemplating additional sources of risk, such as those found in supply chain, technology, competition, raw materials, and management, among others. Although environmental and social risks are not the focus of this study, this work investigated whether these aspects are considered by firms when they perform risk analysis and how their importance is perceived in the decision-making process. Despite the importance of safety risk in any industry, the authors opted to not include these risks in the current analysis. As observed by revising the literature (Wu e*t al*. 2017; Nair 2011) and considering practical experience, safety issues are mostly evaluated after the decision on new investments, and are usually practiced in later stages, such as the design and the operation of a facility.

Three hypotheses were defined for this study, and a questionnaire was developed to validate them.

Hypothesis 1 (H1): Less complex risk assessment methods are more commonly used by the bio-based industry. More specifically, qualitative risk assessment and deterministic risk assessment are preferred over probability analyses. Qualitative tools are usually less complex, need less detailed information, and may provide information for further quantitative analysis (Stuart and El-Halwagi 2013). Among quantitative assessments, sensitivity analysis dominates over other risk assessment methodologies (such as probability analysis) due to its simplicity and direct interpretation of outcomes (Ho and Pike 1991; Pike 1996; Hytönen and Stuart 2012).

Hypothesis 2 (H2): When performing financial risk assessment, price and cost-related uncertainties are primarily considered over other risk sources. The authors' previous review has shown that mainly price and cost-related uncertainties (*e.g.*, variations in raw material costs and prices of final products) are considered during financial risk analysis for investments (de Assis *et al.* 2017a). Other sources of uncertainty, such as technical feasibility, intellectual property, regulations, sales volumes, and market competition, are less commonly evaluated.

Hypothesis 3 (H3): Although risk analysis for investments is performed by organizations, its outcomes are not extensively considered in the decision-making process. Organizations rely on deterministic financial methods rather than probabilistic methods for decision-making. Before the access to computational tools became popular, researchers believed that more complex techniques, such as probabilistic analysis, would have difficulty gaining acceptance by managers and would reduce their enthusiasm for

investments (Ho and Pike 1991). Previous studies indicate that a relatively small number of companies have been regularly using probabilistic risk assessment (Pike 1996), and two-thirds of the forest products industry respondents have not used risk simulation frequently (Ho and Pike 1991, 1998; Hogaboam and Shook 2004).

METHODOLOGY

Questionnaire Preparation

A survey questionnaire was used to collect data for this study (available in Appendix 1). The questionnaire was prepared using the Google Forms application and consisted of two sets of questions, one aimed at respondents who perform risk analysis for investment assessment and another set for respondents who do not perform risk analysis. The initial version of the questionnaire was developed from risk analysis and management literature across various industries, including previous studies focused in the forest and bioproducts industry (Bailes *et al.* 1979; Cubbage and Redmond 1985; Ho and Pike 1991, 1992; Pike 1996; Hogaboam and Shook 2004). The questionnaires were then modified based on comments from experts in the areas of risk and investment management, finance, organizational behavior, supply chain, forest products industry, and survey development, all of them from the Department of Forest Biomaterials and the Poole College of Management at North Carolina State University, and from the Department of Statistical Science at Duke University. The questionnaire was refined to minimize ambiguity in questions and ensure the evaluation of the hypotheses. The updated questionnaires were submitted for a second round of reviews to the same group of experts.

The final version of the questionnaire was organized as follows: the first question identifies whether the respondent uses risk analysis for investment assessment. For those who responded affirmatively, they were then asked 15 questions concerning risk analysis practices, analytical approaches used, sources of risk usually considered, and how risk assessment results were used in the investment decision-making process. For survey participants who responded negatively on the use of risk analysis for investment assessment, 5 questions were asked aiming to identify the reasons for not adopting such practices. Finally, all respondents were requested to provide individual and organizational demographic information, and their contact email as an optional input. The entire questionnaire was designed in a multiple-choice setup, and additional space was provided for comments.

Sample

As previously mentioned, the survey targeted organizations within the bioeconomy, which included firms primarily involved in forestry activities and affiliated organizations that used bio-based feedstock – the so-called bio-based industries (Golden and Handfield 2014; Golden *et al.* 2015; USDA 2016).

A final sample of 2,040 participants was selected for the survey, representing over 220 organizations. This includes an email distribution list (1,927 contacts) from "The Technical Association of the Pulp and Paper Industry" (TAPPI), comprising of managers and upper level employees in the pulp and paper and related industries. The email body to this group (available in Appendix 2) included a brief explanation of the survey goals and the time estimated to complete the questionnaire, the link to the questionnaire, and assurance of confidentiality. The first electronic invitation to this group was sent in

February of 2018. Two reminders to non-respondents were sent, one in May and another in June of 2018.

Additional 119 respondents (indicated as direct contacts) were individually contacted by email. These contacts hold decision-making positions, managerial or upper level employment in the pulp and paper, forest management, engineering, consulting, fuels, chemicals, biomaterials, personal care, wood products, and timberland organizations. The direct contacts list was put together with advice from the Department of Forest Biomaterials / NC State faculty and their networks. In addition, direct contacts' emails were gathered from publicly available online information (such as press releases, reports, or conference presentations). Emails were sent between March and June of 2018, with one email reminder to non-respondents. Only one email reminder was sent because the people in this list are known by the authors and consequently were more likely to respond.

From the TAPPI mailing list, it was possible to identify the number of participants that opened the message. For this group of participants, the response rate was calculated based on the number of messages opened. For the direct contact list, the response rate was based on the number of messages delivered. Response rates varied between the two groups contacted, as shown in Table 1. Response rates were considerably higher for the direct contacts group, as expected. The overall response rate was 22%.

Table 1. Contacted Participants and Response Rates

TAPPI Mail List		**Direct Contact**		**Overall**	
Sent messages	1,927	Sent messages	119	Sent messages	2,046
Opened messages	341	Delivered messages	113	Opened / delivered	454
Responses	61	Responses	39	Overall responses	100
Response rate	**18%**	**Response rate**	**35%**	**Response rate**	**22%**
				Relevant responses	**86**
				Adjusted response rate	**19%**

From the initial 100 responses collected, 14 were excluded for the following reasons: the organization was not directly related to the bio-based industry (*e.g.*, equipment and chemical suppliers for the bio-based industry), duplicate responses (same person responding twice – in this case the first response was recorded), responding organization was a research center or university, and incomplete responses. Thus, with a total of 86 selected responses, the overall response rate was 19%, which is in accordance with previous voluntary surveys (Oblak and Helm 1980; Cubbage and Redmond 1985; Ho and Pike 1991; Shao and Shao 1996; Hogaboam and Shook 2004).

The IBM SPSS Statistics 25 software (IBM Corp., Armonk, NY, USA) was used to conduct statistical analysis. Differences between responses from the two groups (TAPPI and direct contacts) were verified by chi-square tests. Responses evaluated comprised risk assessment practices (existence of guidelines and dedicated department, frequency of use, methodologies, software, analytical approaches adopted, and major sources of risk considered), financial metrics considered for investment assessment, and demographic information. It was confirmed that the TAPPI contacts group was mainly composed by the pulp and paper segment, while direct contacts presented a more diverse group of people. Except for the question related to industry segment, no significant differences between the responses from the two groups were found; thus, results will be presented as a single group.

RESULTS AND DISCUSSION

Survey Demographics

Demographic information provided by survey respondents was validated using information from Hoover's Company Profiles. The 86 respondents belonged to at least 65 different organizations (10% did not provide organization information). Most respondents were from the pulp and paper segment (Table 2).

Table 1. Demographics of Survey Respondents

Industry Segment	**Nº**	**%**
Pulp and paper	48	56%
Chemicals / Fuels / Materials	11	13%
Consulting	10	11%
Consumer products / Personal care	5	6%
Forest management	5	6%
Wood products	4	5%
Others	3	3%
Number of Employees	**Nº**	**%**
< 100	23	27%
100 to 1,000	21	24%
1,000 to 5,000	8	9%
5,000 to 10,000	12	14%
> 10,000	22	26%
Revenue (Million USD)	**Nº**	**%**
< 1	8	9%
1 to 10	12	14%
10 to 500	13	15%
500 to 1,000	7	8%
1,000 to 10,000	19	22%
> 10,000	16	19%
No revenue / No information	11	13%
Headquarters Location	**Nº**	**%**
U.S. or Canada	54	63%
Europe	11	14%
Latin America	12	13%
Asia Pacific	7	8%
Africa	2	2%
Respondent Position	**Nº**	**%**
C-suite / President	18	21%
Upper management	16	18%
Middle management	35	41%
Other positions	17	20%

Nº – Number of respondents / % - Percentage of respondents

Organizations' size varied broadly, with 26% of the respondents representing companies with more than 10,000 employees, and 27% of companies with less than 100 employees. Organizations' revenue was also widely distributed, varying from less than USD 1 million to more than USD 10 billion. Around 13% of respondents did not provide revenue information (mostly startups or private firms). The number of employees and firm revenue was strongly correlated ($R^2 = 0.83$), so the organizations were grouped as small (< 100 employees, revenue < 10 million USD), medium (100 to 5,000 employees, revenue

between 10 to 1,000 million USD), and large (> 5,000 employees, revenue > 1,000 million USD). The categorization resulted in 23 small, 29 medium, and 34 large organizations.

Most of the respondents represented organizations headquartered in the U.S. and Canada. Overall, 56% of the respondents were from local organizations and 44% from multinationals. Approximately 80% of the respondents hold management positions (21% held C-suite or presidential positions; 18% were vice-presidents or directors - upper management, and 41% were managers or coordinators - middle management). The remaining were engineers, scientists, specialists, and analysts.

Risk Analysis Practices in Capital Budgeting for the Bio-based Sector

The use of risk analysis for capital budgeting relative to organization's size is illustrated in Fig. 1. Overall, 98% of respondents indicated that risk analysis is considered during the capital budgeting process, with 76% indicating that it is always considered, and 22% signaling that it is sometimes considered. Statistical analysis shows that larger organizations tend to perform risk analysis more often than smaller organizations. No significant statistical difference was found between pulp and paper and other industry segments concerning the use of risk assessment practices (chi-square = 0.74).

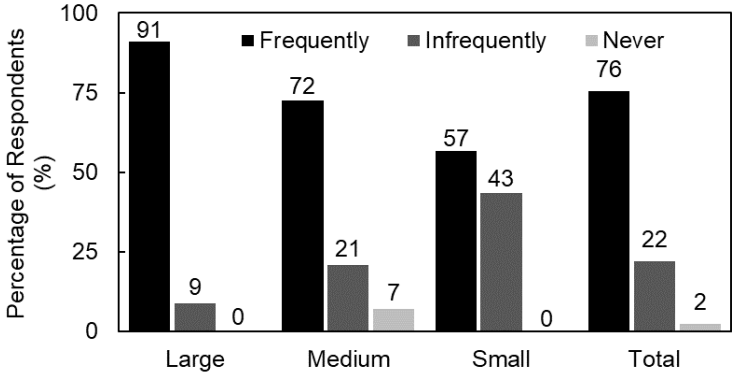

Fig. 1. Use of risk analysis by organization size

For respondents who performed risk assessment, it was investigated whether risk analysis was formalized, which factors, if any, were mostly considered during risk analysis practice, and how risk assessment was considered in the investment decision-making process.

Among the organizations that used risk analysis, approximately half of them (54%) had written guidelines or procedures, and only 42% had a formally dedicated department or employee to conduct risk assessment (Fig. 2a and b). It is worth noting that responses within an organization were not unanimous in recognizing the existence of a written procedure or a dedicated risk analysis department.

There were 22 respondents representing 10 companies who provided contradictory feedback regarding the existence of these instruments. Therefore, it is evident that risk analysis definition and practices are still not widespread among decision-makers. Statistical analysis results showed that formalized procedures of risk analysis are more common in large companies (chi-square = 0.005), as well as a formally dedicated department (chi-square = 0.031).

Risk analysis procedures were more prevalent in European-headquartered organizations (75% of them indicated to have a formalized risk assessment procedure, compared to approximately 50% for organizations with headquarters in other locations). However, the existence of a dedicated department was less common: only 30% of Asian-Pacific headquartered locations had a dedicated department, compared to an average of 43% for other locations.

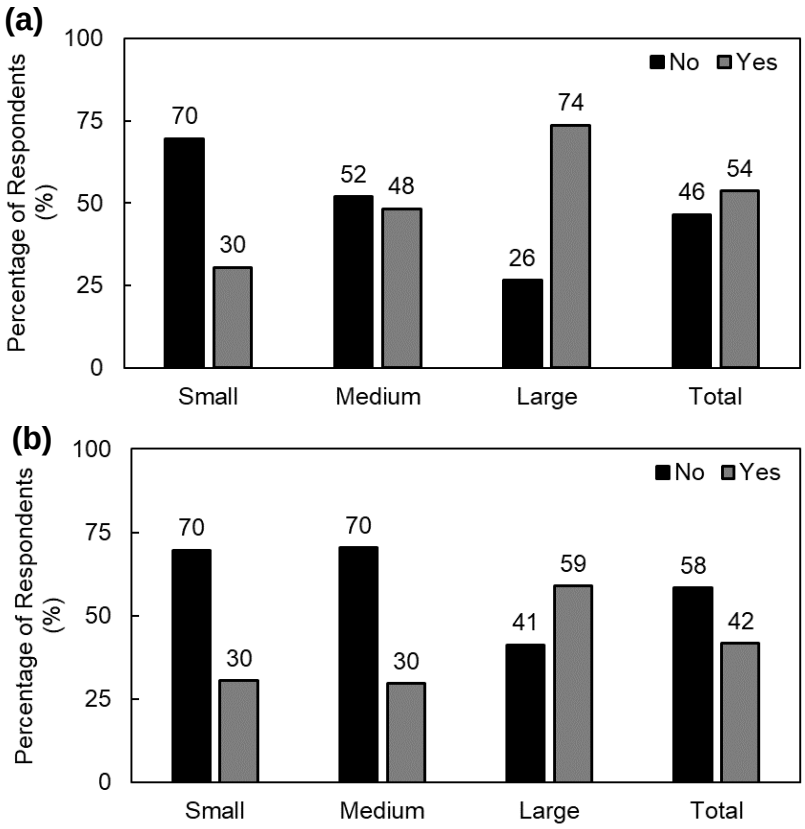

Fig. 2. (a) Availability of written guidelines or procedures for risk assessment by organization size; (b) Existence of a formally dedicated department for risk assessment by organization size

Use of Risk Assessment in Capital Budgeting

Approximately one-third of respondents (30%) have indicated that risk analysis is performed for every investment, and 40% used it only for investments over a minimum value. One-fourth of the respondents did not have a defined criterion on the use of risk analysis. The remaining respondents (5%) indicated that risk analysis was used according to customers' requirements or on a defined schedule (*e.g.*, annually).

The use of risk analysis in different project phases was also examined. It was found that risk assessment is mainly performed during feasibility stages, with more than 80% confirming risk assessment application (Table 3). Less than half of respondents confirmed the use of risk assessment practices during initiation and conception phases, the so-called project early stage phases. It was expected that risk assessment would be used more frequently at these stages, as there are more uncertainties and unknowns at initial project phases (Smith 2000). The use of risk analysis at different project phases is not dependent on organization size or participant position (chi-square > 0.05).

Table 2. Frequency of Risk Assessment Application by Project Phase and Organization Size

Organization Size (Nº)→ Project Phase ↓	Small (23)		Medium (27)		Large (34)		Total (84)	
	Nº	%	Nº	%	Nº	%	Nº	%
Initiation	10	43%	12	44%	11	32%	33	39%
Conception	11	48%	10	37%	18	53%	39	46%
Feasibility studies	19	83%	21	78%	30	88%	70	83%
Engineering design	12	52%	10	37%	23	68%	45	54%
Execution	12	52%	13	48%	17	50%	42	50%

Nº – Number of respondents / % - Percentage of respondents

The authors believe that there should be more emphasis on the use of risk analysis in investment assessment at early stages by both academic and industrial organizations. Although the cumulative cost of an investment is not significant at the early stages, there are more uncertainties and unknowns at initial project phases (Smith 2000; Rocque 2003), and the decisions made at the early stages highly impact major project aspects, such as investment value and project revenue. The use of risk analysis during the early stages of a project is vital for a comprehensive project assessment and allows the formulation and preparation of mitigation strategies, thus reducing the risk of investment failures. The authors believe that research centers and the R&D community will greatly benefit from risk analyses at early-stages as well, because these type of analyses can efficiently guide research, uncovering the drivers with higher financial, environmental, and marketing impacts on the resulting technology or product (*e.g.*, raw materials and inputs used, process yields, and technologies selected).

Tools and Methodologies Used in Risk Assessment for Investment in the Bio-based Sector

Analytical approaches commonly used for risk assessment were investigated (Table 4). The qualitative risk analysis tool to evaluate strengths, weaknesses, opportunities, and threats (SWOT) was reported to be the most used (by 64% of respondents), prevailing over quantitative tools. Qualitative tools are usually less complex, needing less detailed information, not requiring the use of sophisticated software, and providing information for further quantitative analyses (Stuart and El-Halwagi 2013). Worst-case analysis was the most used quantitative tool, followed by decision trees and what-if analysis (which can be either qualitative or quantitative). The use of decision-trees has increased when compared to previous studies. Hogaboam and Shook (2004) found an adoption rate of 20% for the forest products industry *vs.* 37% for the present study). More complex risk assessment tools, such as probability distribution, were reported to be used by approximately one third of respondents. Approximately 10% of the respondents reported that no analytical approaches were used to assess risk, presumably due to their reliance on discussions or no formal procedures. Tornado diagrams and risk heat maps were more common for large organizations (chi-square < 0.05), although their adoption was lower than 40%. Cost-benefit analysis was an option in the original questionnaire, but it was excluded from the analysis because it is not a risk assessment tool. Overall, spider plots and risk heat maps were the less popular methods. Care should be taken when analyzing these results, because respondents may not be aware of all approaches available within their organizations. Additionally, although the possibility to add other methods was provided, not all the

existing practices were listed as options to respondents. For instance, real options and post-mortem analysis were not included in the default list and were not mentioned as other by any of the respondents.

Table 3. Use of Analytical Approaches to Assess Risk by Organization Size

Type of Assessment*	Organization Size (Nº)→ Analytical Approach ↓	Small or Medium (50)		Large (34)		Total (84)	
		Nº	%	Nº	%	Nº	%
Qual.	SWOT analysis	30	60%	24	71%	54	64%
Qual. / Quant-D	What-if analysis	18	36%	12	35%	30	36%
Semi-quantitative	Risk heat map	6	12%	12	35%	18	21%
Quant.-D	Worst-case analysis	20	40%	16	47%	36	43%
Quant.-D	Decision trees	15	30%	16	47%	31	37%
Quant.-D	Switching value table	11	22%	13	38%	24	29%
Quant.-D	Tornado diagrams	6	12%	11	32%	17	20%
Quant.-D	Spider plots	6	12%	9	26%	15	18%
Quant.-P	Probability distribution	12	24%	14	41%	26	31%
-	None	6	12%	2	6%	8	10%

* Qual. = qualitative approach, Quant.–D = quantitative approach /deterministic analysis, Semi-quantitative = approach with qualitative and quantitative characteristics, Quant–P = quantitative approach / probabilistic analysis. Some approaches may be performed through either a qualitative or a quantitative fashion.
Nº – Number of respondents / % - Percentage of respondents

Regarding the use of software, spreadsheets were the most popular tool to perform risk analysis (82% of adoption), followed by software internally developed, although its adoption was significantly lower (23%). Probability assessment software (@Risk and Crystal Ball) presented less than a 10% adoption rate, being used only by respondents from medium and large organizations. Some respondents performed only qualitative risk assessments, which explains why computational software was not used. One respondent emphasized that more time was spent on internal discussion than on software-assisted methodologies.

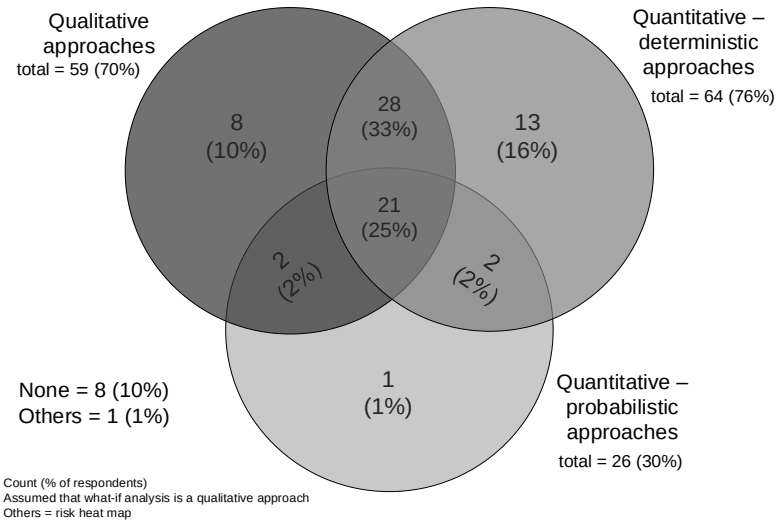

Fig. 3. Quantity and percentage of respondents using different analytical approaches for risk assessment.

Figure 3 illustrates how different approaches are distributed. Qualitative and quantitative deterministic assessments were used by 70% and 76% of the respondents, respectively, while probabilistic assessments were used by 31% of the participants. It is more common to combine qualitative and deterministic assessments (33% of participants) than qualitative and probabilistic (2%) or deterministic and probabilistic assessments (2%). One-fourth of the respondents (25%) used all three types of approaches.

The findings discussed earlier confirm Hypothesis 1, which indicates that less complex risk assessment methods are preferred in the bio-based industry. The SWOT analysis provides direct and simple risk assessment. The same applies for worst-case analysis and decision-trees. In addition, the use of Excel spreadsheets rather than specific software confirms the preference for simpler methods. It is known that probabilistic analyses are more complex and more difficult to perform; however, participants from previous surveys have agreed that it improves decision quality and confidence (Ho and Pike 1992).

Major Sources of Uncertainty Considered for Risk Analysis

This study examined the sources of risk normally considered during investment assessment; in addition, participants were asked to indicate the three major sources of uncertainty that should be considered for risk assessment. The goal of those questions was to assess the perception of uncertainty factors, as well as to validate Hypothesis 2.

When questioned about the main sources of uncertainties considered during investment assessment, respondents indicated an average of seven different sources from the fourteen listed. Prices, costs, and market and sales were the most selected, overall. Statistical results showed that there was no relevant divergence between major sources of risk by organization's size, except for environmental regulations, which is considered more commonly by large organizations (chi-square = 0.036). Less common sources of risks selected by respondents were management, social factors, and sustainability. Overall, the consideration of price and cost-related uncertainties was an important factor for most respondents, which confirmed Hypothesis 2.

Perceptions on the three most important sources of risks for decision-making showed similar patterns (Table 5). Financial risks were the most selected by all respondent levels, followed by market and sales. Statistical analysis showed that competition was more important for the group composed of C-suite, presidents, and upper management (chi-square = 0.016) than for lower level positions, while technology was considered to be more important for respondents at lower levels (middle management and others – chi-square = 0.027) within organizations.

Only 9% of the C-suite and upper management participants considered technology among the top three. It might be the case that lower management levels are more concerned about technology risks, because they are more involved in project details than upper management. The same is valid for upper managers, which are more concerned on competition rather than technology (because the formulation of strategies is part of their day-to-day responsibilities). The selection of other factors (resources, management, government policies, timing, supply chain, R&D, social, environmental regulations, and others) is not dependent on the position of the participants (statistical analysis indicated chi-square > 0.05).

Table 4. Perceptions on the Top Three Sources of Risk, by Respondent Position*

Respondent Level (Nº) → Sources of Risk ↓	C-suite / President / Upper Management (33)		Middle Management Other Levels (51)		Total (84)	
	Nº	%	Nº	%	Nº	%
Financial (*e.g.*, price and cost variation)	23	70%	35	69%	58	69%
Market (*e.g.*, product adoption)	21	64%	26	51%	47	56%
Technology	11	33%	21	41%	32	38%
Operational	9	27%	16	31%	25	30%
Engineering	3	9%	15	29%	18	21%
Competition	11	33%	6	12%	17	20%
Resources	4	12%	7	14%	11	13%
Timing	2	6%	8	16%	10	12%
Environmental regulations	3	9%	5	10%	8	10%
Supply chain	3	9%	4	8%	7	8%
R&D	2	6%	4	8%	6	7%
Management	3	9%	3	6%	6	7%
Social	2	6%	1	2%	3	4%
Government policies	2	6%	1	2%	3	4%
Others**	0	0%	1	2%	1	1%

* Respondents were asked to select the top three sources of risk that should be considered for investment assessment; ** One respondent indicated operational safety and health impact as "others"
Nº – Number of respondents / % - Percentage of respondents

Perceptions on the Benefits of Performing Risk Analysis

Next, this study assessed whether organizations and respondents were aware of the benefits from performing risk assessment. Most of the respondents indicated better understanding of risks for decision-making (58%), reduction of project failures (54%), and development of mitigation strategies (49%) as perceived benefits. In contrast, compliance with regulatory requirements was seen as a benefit by only 6% of the respondents. The perception of the benefits did not vary significantly by company size or respondent position.

When asked whether organizations' management was aware of the benefits of performing a risk assessment, 87% of the respondents confirmed it, 12% were not sure, and only 1% believed their management was not aware. Although the perceptions on risk analysis practices and tools may differ, the bio-based industry is conscious of the innumerous benefits of performing risk assessment (Ho and Pike 1992; RIMS and Advisen Ltd. 2013; Miller *et al*. 2015; Pkhakadze 2016).

Use of Risk Analysis in Investment Decision-making

Finally, this study investigated how risk analysis was used in the decision-making process for investments (to validate Hypothesis 3). This study asked respondents how often results from qualitative, deterministic, and probabilistic analyses were used for investment decision-making. Results from the survey indicate that qualitative risk analysis was always considered for decision-making by 65% of the respondents while 58% of respondents always considered deterministic risk analysis (Table 6). Probabilistic analysis was the least

used type of risk assessment for decision-making (25% of respondents always used it and 21% never considered this type of assessment).

The use of qualitative and deterministic assessment for decision-making was not impacted by organization size. However, larger organizations tend to use probabilistic risk analysis for decision-making more often than small and medium organizations (chi-square = 0.035). No significant difference for pulp and paper *vs.* other industry segments was found (chi-square > 0.05). These results validate Hypothesis 3, indicating that probabilistic risk analysis is not extensively considered for decision-making. Although the use of probabilistic analysis tools is limited in the bio-based industry, the authors believe that due to the inherent complexity and unique risks within the bio-based sector, it is crucial to use sophisticated risk analyses from the initial stages of an investment, to ensure value creation in the bioeconomy.

Table 5. Use of Risk Analysis for Decision-Making, by Organization Size*

	Qualitative Assessments			Deterministic Assessments			Probabilistic Assessments		
Size ↓	**Always**	**Some times**	**Never**	**Always**	**Some times**	**Never**	**Always**	**Some times**	**Never**
Large	68%	32%	0%	68%	32%	0%	35%	56%	9%
Small and Medium	64%	36%	0%	52%	42%	6%	18%	52%	30%
Total	**65%**	**35%**	**0%**	**58%**	**38%**	**4%**	**25%**	**54%**	**21%**

Financial Indicators Used for the Evaluation of Investments

There is evidence to believe that financial metrics used by the forest products industry, for capital budgeting purposes, have been changing over the years. Bailes *et al.* (1979) found that organizations in the forest products industry relied on payback and internal rate of return (IRR); payback was used primarily in small revenue organizations, while IRR was most commonly used by larger organizations (Bailes *et al.* 1979). Similarly, Cubbage and Redmond (1985) observed that the forest products industry used IRR, followed by accounting rate of return (ARR), and discounted payback (Cubbage and Redmond 1985). A survey conducted in 2001 confirmed that IRR was still among the preferred criteria for investment assessment, although net present value (NPV) had been gaining space (Hogaboam and Shook 2004). Likewise, studies conducted with the 200 largest UK companies have showed increased adoption of IRR and NPV between 1975 and 1992, due to the increased use of computational tools; however, payback led preference, with 94% of adoption against 81% for IRR and 74% for NPV in 1992 (Pike 1996).

To investigate current practices in the bio-based industry, the authors inquired regarding the types of financial indicators used to assess investment attractiveness as well as those for financial risk assessment. Similar to the most recent findings, IRR and NPV were among the most common metrics used to assess investment attractiveness, in addition to return on investment (ROI) (Table 7) (Cubbage and Redmond 1985; Graham and Harvey 2001; Hogaboam and Shook 2004; Pike 1996). Internal Rate of Return was more common in large organizations, with 94% of adoption rate (chi-square = 0.001). Payback (discounted or non-discounted) was less popular, used by only 21% of the respondents. Other methods listed by respondents include Economic Value Added (EVA), profitability

index, price-to-earnings ratio, Adjusted Present Value (APV), breakeven point, social value, project cost, and productivity ratios (the last being used specifically for forest management organizations). Similar to early studies (Pike 1996), there was a tendency to combine several metrics for financial assessment; 17% of respondents relied on only one financial metric while 60% of respondents used between two and four financial criteria to screen investment options.

Financial indicators commonly used in risk assessment are slightly different from those used for deterministic investment attractiveness. The ROI, IRR, and NPV are among the most used metrics for risk analysis; however, payback has been more extensively considered when assessing investment risk through deterministic analysis.

Table 6. Financial Metrics Used to Assess Investment Attractiveness and to Perform Risk Assessment, by Organization Size*

	Used to Assess Investment Attractiveness						Used for Risk Assessment	
Organization Size → Financial Metric Used ↓	Small and Medium		Large		Total		Total	
	Nº	%	Nº	%	Nº	%	Nº	%
IRR	30	58%	31	94%	61	72%	54	65%
ROI	37	71%	22	67%	59	69%	57	69%
NPV	27	52%	24	73%	51	60%	48	58%
ROCE	15	29%	16	48%	31	36%	25	30%
Payback (Discounted and Non-discounted)	7	7%	11	17%	18	21%	21	25%
Hurdle Rate	8	15%	7	21%	15	18%	12	14%
Other	25	10%	20	12%	45	53%	39	47%

* 85 responses were considered for this analysis because one was not valid (the name of the financial metric used as other was not provided). Other metrics include EVA, profitability index, price-to-earnings ratio, APV, breakeven point, social value, project cost, and productivity ratios.
Nº – Number of respondents / % - Percentage of respondents

CONCLUSIONS

1. More than 95% of the surveyed respondents within the bio-based industry use risk analysis for investment assessment. Qualitative and quantitative deterministic methods dominate over probabilistic approaches.
2. Although risk analysis is adopted by organizations in the bio-based industry, its definitions and practices are still not widespread among decision-makers. Overall, one-fourth of the participants who performed some type of risk assessment did not have a defined criteria, process, or methodology on the use of risk analysis.
3. Larger organizations tend to perform risk assessments more frequently and have formalized procedures with dedicated resources. Approximately one-half of the respondents confirmed the availability of written guidelines or dedicated departments for risk assessment.

4. Less complex tools, such as SWOT and worst-case analysis, are among the most used methods within the bio-based industry, as well as the use of Microsoft Excel as a tool by more than 80% of participants.
5. Price and cost-related risks (financial risks) are the primary sources of risk considered across different organization sizes and management levels. Additional common sources of risks considered are market (volume) and sales, competition, and technology. The perception of major risks varies depending on the decision-maker position.
6. The use of risk assessment in initial project phases is not well established. More than 80% of respondents performed risk assessment in later project stages (feasibility studies), while less than 50% of respondents used risk analysis at earlier project phases (initiation and conception).
7. Internal Rate of Return, Return on Investment, and Net Present Value continue to be the most used financial indicators for investment assessment and risk analysis in the bio-based industry.

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APPENDIX 1

Section 1: Questionnaire Sent to Survey Participants

1.1 Does your organization perform financial risk assessment for investments? This includes quantitative and qualitative methods.

Definitions: Risk Assessment is a methodology used to estimate how often an event may happen and the impact of its consequences. In Financial Risk Assessment, the impact of different risks on the financials of an investment is evaluated. Safety, health and environmental- related risk assessment are not included in this survey.

☐ Frequently (Go to section 2)

☐ Infrequently (Go to section 2)

☐ Never used (Go to section 3)

Section 2: Organizations that Perform Risk Assessment

2.1 Does your organization have a written guideline or procedure on how to perform risk assessment for investments?

☐ Yes

☐ No

2.2 Does your organization have a formally dedicated department / employee to conduct risk assessments for investments?

☐ Yes

☐ No

2.3 How often is risk assessment performed by your organization? (please select only 1 option)

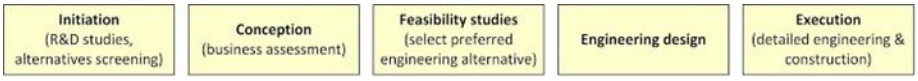
☐ For every investment

☐ Only for investments over a minimum value

☐ Not a defined criteria

☐ Other: _____

2.4 In which project stage(s) does your organization perform risk assessment? (Check all that apply.)



☐ Initiation

☐ Conception

☐ Feasibility studies

☐ Engineering design

☐ Execution

2.5 Which type of methodology does your organization use? (Check all that apply.)
P.S.: Some analytical methods, such as what-if analysis, may be classified either as qualitative or quantitative methodology

☐ Qualitative (non-numerical output is assessed, e.g. SWOT analysis - Strengths, Weaknesses, Opportunities, and Threats)

☐ Quantitative (numerical output assessed, e.g. probability assessment)

☐ Qualitative and quantitative assessments combined

☐ Other: _____

2.6 Which software does your organization use to perform risk assessment? (Check all that apply.)

☐ Microsoft Excel spreadsheets

☐ Software developed "in-house"

☐ @Risk (Palisade)

☐ Crystal Ball (Oracle)

☐ Matlab

☐ DPL (Syncopation Software)

☐ Riskturn

☐ None

☐ Other: _____

2.7 Which of the following analytical approach(es) does your organization use to perform risk assessment? (Check all that apply.)

☐ Tornado diagrams

☐ Spider plots

☐ Switching value table

☐ Probability distribution

☐ SWOT Analysis

☐ Risk heat map

☐ Decision trees

☐ What-if analysis

☐ Cost-benefit analysis

☐ Worst-case analysis

☐ None

☐ Other: _____

2.8 Identify which specific sources of risk are considered by your organization when performing risk assessment. (Check all that apply.)

☐ Technology (e.g. TRL - technology readiness level)
☐ Financial (e.g., cost of raw materials)
☐ Market and sales (e.g., product adoption)
☐ Operational (e.g., not achieving full capacity at start up)
☐ Engineering (e.g., capital investment higher than forecasted)
☐ Competition (e.g., competition leading to loss in market share)
☐ Resources (e.g., lack of personnel)
☐ Management (e.g., poor management)
☐ Government policies (e.g., subsides are not available)
☐ Timing (e.g., delay in start-up)
☐ Supply chain (e.g., raw material sourcing)
☐ R&D (e.g., intellectual property)
☐ Social (e.g., impact of investment in local community)
☐ Environmental regulations (e.g., use of hazardous materials)
☐ Other: _____

2.9 Select the top 3 sources of risk you believe should be considered by your organization when performing risk assessment.

☐ Technology (e.g. TRL - technology readiness level)
☐ Financial (e.g., cost of raw materials)
☐ Market and sales (e.g., product adoption)
☐ Operational (e.g., not achieving full capacity at start up)
☐ Engineering (e.g., capital investment higher than forecasted)
☐ Competition (e.g., competition leading to loss in market share)
☐ Resources (e.g., lack of personnel)
☐ Management (e.g., poor management)
☐ Government policies (e.g., subsides are not available)
☐ Timing (e.g., delay in start-up)
☐ Supply chain (e.g., raw material sourcing)
☐ R&D (e.g., intellectual property)
☐ Social (e.g., impact of investment in local community)
☐ Environmental regulations (e.g., use of hazardous materials)
☐ Other: _____

2.10 Please list the top 3 benefits of performing risk assessment in your organization.

☐ Reduction of project failures

☐ Development of risk mitigation strategies

☐ Better screening between project alternatives

☐ Better understanding of the risks involved when making a decision

☐ Compliance with regulatory requirements

☐ Consistent data for decision-making (standard procedures used for assessing different projects)

☐ Faster response to unexpected events

☐ Organization image

☐ Allows contingencies for projects

☐ Cost savings by identifying systemic risks and mitigating these at organization level

☐ Other: _____

2.11 Is your management aware of the benefits of performing risk assessment for the decision-making process?

☐ Yes

☐ No

☐ Not sure

2.12 Which metric does your organization use to assess investment attractiveness? By investment we mean projects of new facilities, revamp projects, and acquisitions of companies. (Check all that apply.)

☐ NPV (Net Present Value)

☐ IRR (Internal Rate of Return)

☐ ROI (Return on Investment)

☐ ROCE (Return on Capital Employed)

☐ Discounted payback

☐ Non-discounted payback

☐ EVA (Economic Value Added)

☐ Hurdle rate

☐ Price-to-earnings ratio

☐ Profitability index

☐ APV (Adjusted Present Value)

☐ Other:_____

2.13 Which financial metrics are evaluated during risk assessment? (Check all that apply.)

☐ NPV (Net Present Value)
☐ IRR (Internal Rate of Return)
☐ ROI (Return on Investment)
☐ ROCE (Return on Capital Employed)
☐ Discounted payback
☐ Non-discounted payback
☐ EVA (Economic Value Added)
☐ Hurdle rate
☐ Price-to-earnings ratio
☐ Profitability index
☐ APV (Adjusted Present Value)
☐ Other:_____

2.14 How risk assessment outcomes are considered in the investment decision-making process?

	Always considered	Sometimes considered	Never considered
Qualitative risk assessment outcomes (non-numerical outcomes)	☐	☐	☐
Deterministic outcomes (e.g. sensitivity analysis)	☐	☐	☐
Probabilistc outcomes	☐	☐	☐

2.15 Please use this space for any additional comments.

_____

_____

Please proceed to section 4

Section 3: Organizations that Do Not Perform Risk Assessment

3.1 Does your organization have a written guideline or procedure on how to perform risk assessment?

☐ Yes
☐ No

3.2 List possible reasons why your organization is not performing risk assessment for investments. (Check all that apply.)

☐ Unqualified personnel

☐ Tools are not available

☐ Never used before

☐ Procedures are too complicated

☐ Organization is not aware of benefits of performing risk assessment

☐ Other: _____

3.3 Select the top 3 sources of risk you believe should be considered by your organization when performing risk assessment.

☐ Technology (e.g. TRL - technology readiness level)

☐ Financial (e.g., cost of raw materials)

☐ Market and sales (e.g., product adoption)

☐ Operational (e.g., not achieving full capacity at start up)

☐ Engineering (e.g., capital investment higher than forecasted)

☐ Competition (e.g., competition leading to loss in market share)

☐ Resources (e.g., lack of personnel)

☐ Management (e.g., poor management)

☐ Government policies (e.g., subsides are not available)

☐ Timing (e.g., delay in start-up)

☐ Supply chain (e.g., raw material sourcing)

☐ R&D (e.g., intellectual property)

☐ Social (e.g., impact of investment in local community)

☐ Environmental regulations (e.g., use of hazardous materials)

☐ Other: _____

3.4 Which metric does your organization use to assess investment attractiveness? (Check all that apply.)

☐NPV (Net Present Value)

☐ IRR (Internal Rate of Return)

☐ ROI (Return on Investment)

☐ROCE (Return on Capital Employed)

☐ Discounted Payback

☐ Non-discounted payback

☐ EVA (Economic Value Added)

☐ Hurdle rate

☐ Price-to-earnings ratio

☐ Profitability index

☐ APV (Adjusted Present Value)

☐ Other: _____

3.5 Please use this space for any additional comments

_____

_____

Section 4: Organization and Respondent Information

4.1 What is the major industry segment of your organization? (Please check only 1 box)

☐ Fuels Chemicals

☐ Biotech (e.g. enzymes)

☐ Pulp & Paper

☐Personal care

☐ Wood products

☐Other forest products

☐ Forest management

☐ Consulting

☐ Other: _____

4.2 What types of biobased products is your organization producing or aiming to produce? (Check all that apply.)

☐ Biofuels

☐ Biochemicals

☐ Biomaterials

☐ Pulp and paper

☐ Biotech / enzymes

☐ Forest products (e.g., timber)

☐ Forest management

☐ Other:_____

4.3 How many employees are in your organization?

☐ Less than 100

☐ 100 - 1,000

☐ 1,000 to 5,000

☐ 5,000 to 10,000

☐ More than 10,000

4.4 What was your organization's revenue in 2016?

☐ No revenue
☐ Less than USD 1 million
☐ Between USD 1 million and USD 10 million
☐ Between USD 10 million and USD 500 million
☐ Between USD 500 million and USD 1 billion
☐ Between USD 1 billion and USD 10 billion
☐ More than USD 10 billion
☐ No information available

4.5 How would you describe your organization?

☐ Multinational
☐ Local company - U.S.
☐ Local company - other countries

4.6 Where is your organization's headquarters located?

☐ U.S. or Canada
☐ Latin America Europe
☐ Asia Pacific
☐ Africa

4.7 Respondent position _____

4.8 Respondent organization (this information will be used to assure quality of survey results and will be kept confidential).

_____

4.9 To receive survey results before they are published, please enter your email below (optional) _____

End of questionnaire
Thank you for your participation

APPENDIX 2
Email Body Sent to Participants

Dear,

NC State University and Duke University are conducting a survey on the use of financial risk assessment for investments in the pulp and paper and biobased industries.

We kindly ask you to take some time to participate in this survey. It will take 5 - 15 minutes to answer the questionnaire.
To answer the survey, please follow this link: https://goo.gl/forms/SKTHRiRRIQ6Mfufd2

Main goals of this survey are:

1) Assess sources of uncertainty commonly considered for risk assessment
2) Identify which methods are used for assessment of risk in investments
3) Evaluate how risk assessment is considered for decision-making in investments.

Answers will be kept confidential. Respondents will receive a summary of the outcomes before the publication of survey results.

For additional information on this project or questions please contact Camilla Abbati - cabbati@ncsu.edu or Dr. Ronalds Gonzalez - rwgonzal@ncsu.edu.

Best regards,