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Forest biomass and bioenergy supply chain resilience: A conceptual decision-making model

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Abstract

In recent years, with the increasing concerns about the global warming, limited non-renewable energy sources, and uncertainty in renewable energy sources accessibility, how to continuously supply clean sources of energy in form of a resilient system structure has become a topic of intense scholarly interest. Based on the milestone literature on the research field of renewable and non-renewable energies, forest biomass and bioenergy have significant compatibility with both industry and nature. Through this, our proposal contributes to supply one of the most available clean energy sources and direct this type of energy needed in an optimal way. The essential resilience components are determined and classified according to the theoretical and practical concepts. Then, this research is made use of a conceptual decision-making model based on third order confirmatory factor analysis to explore the interactions among the components in form of a network. The results reveal that the proposed model has sufficient validity and reliability levels. Finally, key interactions among the elements of model that contributed to most of the impacts on the forest biomass and bioenergy supply chain resilience were found to be optimized constantly within the network.

Keywords: Forest biomass; Forest bioenergy; Supply chain resilience; Resilient energy development; Conceptual decision-making

1. Introduction

1.1. Global warming, environmental pollution, and limited energy sources: risks and opportunities

Nowadays, the three main concerns of researchers and managers, locally and globally, are the global warming, environmental pollution, and limited energy sources (Hoffmann, Muttarak, Peisker, & Stanig, 2022). By investigating the practical research works and also reviewing the literature, it can be found that the root of all three problems is focusing on the consumption of non-renewable energy sources (Mujtaba, Jena, Bekun, & Sahu, 2022; M. M. Rahman & Alam, 2022; Usman & Radulescu, 2022). The main causes of global warming is the excessive production of greenhouse gases as a result of the use of non-renewable energy sources and their derivatives (Hoffmann et al., 2022; Mujtaba et al., 2022). The reasons for using this type of energy sources include the very high turnover of the global markets of crude oil, natural gas, bitumen and coal as well as its impact on the markets in developed and developing countries (Jeon, 2022). In terms of environmental pollution, non-renewable energy sources play a significant role, which is irreparable in most cases (Hoffmann et al., 2022; M. M. Rahman & Alam, 2022). This type of energy sources through their production derivatives such as fuels, goods. etc., the use of which pollutes the environment (Ramzan, Raza, Usman, Sharma, & Iqbal, 2022). On the other hand, non-renewable energy resources are limited due to their nature and how they are created and will run out in the near future (Hoffmann et al., 2022; Usman & Radulescu, 2022). This problem can significantly affect the industrial and non-industrial structures of countries in the future, and if there is no proper and timely

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replacement, it will cause a vacuum and confusion in the progress in various fields. Although many measures have been taken to solve the mentioned challenges, to achieve a sustainable situation in the field of energy, many practical and theoretical efforts are needed, such as finding alternative sources, technologies, policies, strategies etc. But, the evidences indicate that the targeting, planning and activities in the field of energy are more economic than environmental which is considered a very important obstacle in this way (Jingpeng, Ullah, Raza, & Ahmed, 2022; Tumin, Novikov, Wenhao, Kostromin, & Daneykin, 2022). Therefore, the most important issue in the research community of the energy sector is to find sustainable alternatives to partially or fully meet the need for non-renewable energy sources and their derivatives.

1.2. Biomass and bioenergy: description and their local and global importance

Biomass can be considered as an accessible and renewable energy source which is one of the main alternatives to non-renewable energy sources in developed and developing communities (Dashtpeyma & Ghodsi, 2021). In general, this source of energy includes the series of organic raw material that emanating from plants' and animals' life cycles (McKendry, 2002). In this line, plant-based biomass which has the major portion of the biomass industry is created from green plants converting light particles into organic material via photosynthesis proceeding and consist of an inclusive types of vegetation and relevant wastages (Dashtpeyma & Ghodsi, 2021; McKendry, 2002). Hence, biomass can be considered as a source in interaction with the environment and aligned with it, which will be available in most regions due to its high diversity. On the other hand, bioenergy is a type of renewable energy source produced from biological feedstock, chiefly forest biomass, and is accounts for approximately 10 percent of global entirety primary energy supply in recent years (Agency, 2022). It should be noted that the contribution of the novel types of bioenergy used today, as the significant source of renewable energy, to ultimate energy demand amongst all areas is five times more than entire wind and solar PV consumptions, even if the statistics related to traditional biomass consumption are ignored (Agency, 2022). Moreover, the constant use of this type of renewable energy to meet the needs of electricity and transport biofuels industries has been increasing dramatically, mostly because of the financial and political supports at micro and macro levels (Agency, 2022; Maktoubian, Taskhiri, & Turner, 2021). Accordingly, biomass and bioenergy will play important roles in the development of industries related to clean energy, such as transportation, urban development, and the restoration of ecosystems in local and global level. Therefore, examining the advantages and disadvantages of different types of biomass and bioenergy, as well as prioritizing existing potentials and needs to produce and optimally use them, are important challenges and issues in this field.

1.3. Forest biomass and bioenergy: description and their local and global importance

Forest biomass can be used as energy source by transforming into various physical states, which include gas, liquid and solid, with their own advantages and disadvantages (Canada, 2022; Hall, 2002). This type of biomass often consists of initial residues obtained through forest proceedings, secondary residues obtained through industrial wood conversion proceedings, tertiary residues obtained through destruction, manufacturing, and packaging operations, and finally customary firewood (Thiffault et al., 2011). It is worth mentioning that constant advancement of the biomass sector theoretically and practically, significantly improve the quality and quantity of harvesting capability, productivity, and proceedings that will lead to the optimal amount of biomass gained from a locality in different time periods (Nguyen, Jones, Soto-Berelov, Haywood, & Hislop, 2020; Thiffault et al., 2011). In this line, investigating the forest biomass potentials and needs is fundamental to assess its impacts on the environment and the entire energy sector locally and globally, especially in the bioenergy sector (Dashtpeyma & Ghodsi, 2021; Nguyen et al., 2020). Therefore, improving the efficiency and performance levels in the field of forest biomass industry is one of the challenges that, if solved, in addition to developing clean energy industries and reducing greenhouse gas emissions, it can play a vital role in ameliorating the state of green space at the local and global levels by constructive interacting with nature.

Bioenergy generated from forest biomass by energy-relevant conversion technologies is called forest bioenergy (Canada, 2022). Given the fact that the energy demand, supply, and price have been fluctuating in recent years, greenhouse gases emissions and due to that climate change has been increasing, and there is uncertainty in continuous access to some renewable energy sources, hence the governmental and non-governmental organizations consider forest bioenergy as a sustainable, economic, and environmentally friendly alternative to other sources of energy (Canada, 2022; H. Wang, Zhang, Bi, & Clift, 2020). In general, forest bioenergy is produced from wood residues collecting through the timber harvesting and within the wood manufacturing industry, such as wood pellets, black liquor, and recovered wood waste (Berger et al., 2013; Canada, 2022). For the constant development of this type of energy, a continuous and constructive interaction and balance must be created between forests, needs and technologies. In fact, quality and quantity of bioenergy sector at various levels can be influenced by many factors such as demand-supply processes in industrial and non-industrial environments, local and global policies, environmental potentials, and technical and managerial developments (Canada, 2022; Dashtpeyma & Ghodsi, 2021). Due to the reasonable price, availability and less environmental pollution, the supply and demand of bioenergy is increasing (Canada, 2022). Therefore, designing an efficient system structure for the mentioned sector based on optimal targeting, planning and activities should be considered as a vital issue for enhancing the performance quality and ensuring a guaranteed future (Dashtpeyma & Ghodsi, 2021).

1.4. Forest biomass and bioenergy supply chain: description and their local and global importance

Forest biomass and bioenergy supply chain (SC) is defined as "a network among the forests, biomass producers, biomass distributors, bioenergy producers, bioenergy distributors, and final consumers associated with each of them" (Dashtpeyma & Ghodsi, 2021). It includes a wide range of individuals, organizations, resources, software and hardware technologies, all the physical and non-physical routes, procedures, and outcomes to provide the related products or services (Shabani, Akhtari, & Sowlati, 2013). In energy and forest industries, the quality and quantity of the SC's goals and plans play the significant roles in developing a comprehensive framework to do functions strategically (De Meyer, Cattrysse, Rasinmäki, & Van Orshoven, 2014). Therefore, the constant advancement of industries working on the forest biomass and bioenergy fields considerably lies at the back bone of the condition of the SC's performance (Dashtpeyma & Ghodsi, 2021). In fact, the forest biomass and bioenergy SCs can help the producers, distributors, and consumers in energy sector to better comprehend the goals, plans and activities included in the entire network leading to sustainable forest-based industries in different situations (Dashtpeyma & Ghodsi, 2021). In this line, feature of raw material, economic situation, demand fluctuation, etc. can affect the levels of forest-based bioproducts and consumptions because of diversity and changeability (Shabani et al., 2013). Therefore, a procedure should be determined to decrease the instability in the costs and revenues more than other types of energy as well as improving the quantity and quality of inputs and outputs in the forest biomass and bioenergy supply chain network (SCN) considering the different principals affected by uncertainty (Shabani et al., 2013). It indicates that the adaptability with the uncertainties, potentials, and needs in the mentioned field effectively improve the performance within the flows and processes in the renewable industry based on the well organizing the demand and supply rates in line with operation in various levels (Cambero & Sowlati, 2014). Moreover, integration of the environmental, economic, social, technical and strategic potentials and needs in industries related to the forest biomass and bioenergy sectors is an essential issue to reach a prospective system structure as well as improve fundamental capabilities in this way (Cambero & Sowlati, 2014). Hence, identifying and evaluating the prerequisites and drivers of the sustainable forest biomass and bioenergy SCN can play a positive role in optimizing the performance quality in upstream, internal, and downstream functions.

1.5. Forest biomass and bioenergy supply chain resilience: description and their local and global importance

Nowadays, a resilient structure can play an important role in optimizing the performance level in SCNs leading to gain more and sustainable advantages and portions in business environments (Dashtpeyma & Ghodsi, 2019). Resilience is defined as a capability to upgrade the potentials of individuals or systems to fulfill the functions efficiently, commensurate with predetermined goals and plans, within uncertain conditions (Dashtpeyma & Ghodsi, 2019; Kamalahmadi & Parast, 2016; Sangari & Dashtpeyma, 2019). Therefore, this capability has an undeniable impact on the functions of the SCN. For the first time, a comprehensive definition for forest biomass and bioenergy SCR is presented in a research by Dashtpeyma and Ghodsi (Dashtpeyma & Ghodsi, 2021). Accordingly, forest biomass and bioenergy SCR refers to the "the capability of forest biomass and bioenergy SCN to return from sustained difficulties, for sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards" (Dashtpeyma & Ghodsi, 2021). By this insight, resilience capability can positively affect the SC performance in the relevant industrial and non-industrial environments, by improving the ability of SCN to make balance among the goals, plans and activities, properly. It is necessary to investigate the influence of effective resilience components on SC functions (Dashtpeyma & Ghodsi, 2019, 2021). Therefore, working on optimizing SCR will be an important mission in the research community of this field in the coming years.

1.6. Contribution: importance and difference of the current paper

As mentioned, there are only a few studies within the relevant literature pertaining to the improvement of resilience capability during process and flows in forest biomass and bioenergy SCs, particularly (Dashtpeyma & Ghodsi, 2021) meeting the part of the needs in this area in terms of quality and quantity. Existing study, as the first comprehensive research on the forest biomass and bioenergy supply chain resilience (SCR), focuses more on reviewing the resilience components of the field, while today's requirement is to design, deploy, develop, and optimize a resilient system structure. Therefore, conducting the detailed, prospective, and practical research on this field is a critical issue for active members in the relevant academic environments.

There are so many reasons for the expansion of resilience concept in forest biomass and bioenergy SCs which have not been given enough attention. For instance, resilience capability can improve the quality and quantity of community and interactions in such business environments (Dashtpeyma & Ghodsi, 2021; Podesta, Coleman, Esmalian, Yuan, & Mostafavi, 2021). It is invaluable in helping decision makers to investigate the conditions into prioritizing the collaborations with other communities in processes and flows without resilient structure (Dashtpeyma & Ghodsi, 2021; Podesta et al., 2021). Also, constant changeability, as a resilience necessity, is a fundamental feature for an efficient network (Dashtpeyma & Ghodsi, 2021; Tarigan, Simatupang, & Bangun, 2021). Indeed, it positively affects the processes of preparation and anticipation, coping and improvisation, and recovery (Dashtpeyma & Ghodsi, 2021; Tarigan et al., 2021). Moreover, constant development and improvement is one of the characteristics of resilient structures that can significantly impact on the performance level (Dashtpeyma & Ghodsi, 2021; Siagian, Tarigan, & Jie, 2021). This element can play an important role in updating requirements and adapting them to potentials. Therefore, an optimal resilient system structure for a network, especially in forest biomass and bioenergy sector, can significantly upgrade the efficiency and performance levels in foreseeable and unforeseeable conditions. That's why in recent years, addressing the issue of resilience optimization in all the fields has received much attention.

Consequently, by reviewing the theoretical background of the forest biomass and bioenergy SC, a significant research gap can be realized that includes a knowledge-based investigation on practical aspect of the resilience capability, relevant components, and interactions among them in different levels within the network. Therefore, it is essential to develop a conceptual decision-making framework to assess the influential components of resilience in this sector as a changeable complex. This research aims to bridge the mentioned research gap.

In the following, the research questions are presented to achieve an argumentative insight on the research process and the findings:

- What are the existing research gap and necessities of forest biomass and bioenergy SCR?
- What are the effective resilience components for forest biomass and bioenergy SC?
- What is the type of relationships or interactions among the resilience components and entire forest biomass and bioenergy SCR?
- What are the research and managerial implications to design, deploy, develop, and optimize a resilient system structure for forest biomass and bioenergy SC?

The research hypotheses also include the existence or non-existence of the relationships or interactions among the resilience components and entire forest biomass and bioenergy SCR.

Therefore, this paper aims to develop a conceptual decision-making model based on a multi-layered method to design a resilient forest biomass and bioenergy SC by determining an efficient system structure and optimal relationships between all the components.

2. Research process

In this study, a conceptual decision-making model is developed to help the SC managers and researchers in different situations investigate the most important components pertaining to the resilience capability leading to productive incomes and outcomes at different levels. The proposed model uses components including barriers, enablers, KPIs, practices and potential stakeholders required to develop and optimize the resilient forest biomass and bioenergy SC. In the following, details of the components of the proposed model and the method used will be described.

2.1. Barriers of the forest biomass and bioenergy SCR

Identification of the barriers of enhancement in the forest biomass and bioenergy SC is a fundamental issue leading to solve the problems quickly. In this line, the resilience barriers of forest biomass and bioenergy SC negatively affect the entire structure of SCN. It can be divided into five categories including environmental, economic, social, technical, and strategic to cover all critical aspects (Dashtpeyma & Ghodsi, 2021). In fact, by evaluating the barriers of resilience capability, the reasons and procedures to deal with the existing challenges in such SC will be clearer for managers and researchers.

2.2. Enablers of the forest biomass and bioenergy SCR

Identification of the enablers of enhancement would be invaluable in optimizing the system structures within SCN. The resilience enablers of forest biomass and bioenergy SC positively affect the entire structure of the entire structure of SCN. It can also be divided into five categories including environmental, economic, social, technical, and strategic to cover all critical aspects just like barriers (Dashtpeyma & Ghodsi, 2021). Indeed, by evaluating the enablers of resilience capability and enhancing them, the potentials of the network structure will be strengthened based on prioritizing effective factors. Business managers are continuously enhancing the best components to promote the performance quality in different levels (Cabral, Grilo, & Cruz-Machado, 2012). Some barriers or enablers have more impact on forest biomass and bioenergy SC and some have less impact on it.

2.3. Key performance indicators (KPIs) of the forest biomass and bioenergy SCR

A KPI is a computable content that indicates the ability of an entity to obtain the main goals by an efficient way (Carvalho, Azevedo, & Cruz-Machado, 2010). Indeed, entities in forest biomass and bioenergy SC sector implement the KPIs in different situations to assess the achievements pertaining to the goals. Preferred KPIs are often centralized on the overall performance of entities, whiles non-preferred KPIs are often centralized on processes in subsidiaries of entities (Forkan et al., 2019). In this research, the attempts are made to determine the most important KPIs for forest biomass and bioenergy SCR. The main reason to prove the relevance of these KPIs is their relations with the SMART criteria so that they are specific, measurable, attainable, relevant, and time-bound within SC processes and flows. Another feature of these KPIs is their potentials to be evaluated and re-evaluated. It will help the researchers and managers to more accurately assess the interactions between KPIs and other effective components.

2.4. Practices of the forest biomass and bioenergy SCR

The practices and strategies are effective tools for SC managers to improve the performance quality (Cabral et al., 2012). Taking advantage of the best resilience practices in forest biomass and bioenergy SC will lead to growing development and achievement. The perspective entities face the challenge of how to select the appropriate practices, which in turn affects their performance quality in the upstream, internal and downstream processes and flows. Hence, it is necessary to understand the relationships between the practices and other effective components impacting on resilience level in forest biomass and bioenergy SCN. It should be noted that some practices have significant effect on a series of characteristics and insignificant on others. Therefore, the importance of the resilience practices needs to be investigated from various aspects. In this line, resilience main factors were considered as practices in the evaluation process that significantly impact on developing a resilient forest biomass and bioenergy SC in uncertain situations. The main reason for considering the resilience main factors as practices is due to their importance in improving the quality and quantity of inputs and outputs for a forest biomass and bioenergy SCN from the beginning to the end of the SC functions (Dashtpeyma & Ghodsi, 2019, 2021; Sangari & Dashtpeyma, 2019).

2.5. Potential stakeholders of forest biomass and bioenergy SC

Stakeholders play key roles in determining the value of the goals and plans within a forest biomass and bioenergy SCN and financial or non-financial outcomes at the end. Stakeholders include a wide spread range of actors that effectively lobby between business and non-business organizations or between governmental and non-governmental entities to achieve specific and common advantages (Rozbicka, Kamiński, Novak, & Jankauskaitė, 2021). The lobby, positively or negatively, affects the decision-making process to assimilation of public or private policies (Rozbicka et al., 2021). Hence, existing the different insights and demands of potential stakeholders can cause many challenges such as conflict of interest in local or international business environments. The management of the potential stakeholders at the right time and place can integrate the internal and external parties leading to improve their supports quality and quantity as well as increasing the feasibility of the forest biomass and bioenergy SC goals and plans (Kaiser, 2021). Therefore, as an important part of the forest biomass and bioenergy SCN, the potential stakeholders have undeniable effects on resilience level of the SCs in various circumstances.

It should be noted that:

- Forest biomass and bioenergy SC consists of relationships and interactions among and against their performers in the state of dependence and non-dependence.
- There are differences in how procedures are understood and applied to barriers, enablers, KPIs, practices, and potential stakeholders based on performers and levels.
- Components in different situations may have contradictory results. Sometimes, to improve one case, another one should be limited.
- All of the resilience components and their subsets for forest biomass and bioenergy SC are important, so that the differences are about the type and amount of effectiveness.
- The proposed model provides the details for managers and researchers focused on forest biomass and bioenergy SCN to do relevant functions, efficiently and accurately.

- The proposed model provides a situation to finding out the relationships and interactions among the SC functions, potentials and needs directly and visually leading to efficiently dealing with the great challenges or opportunities and managing them.

Overall, the proposed conceptual decision-making model can play significant role in improving the quantity and quality of goals, plans, and activities or functions as well as increasing the positive rate of willingness to use, ease of use, usefulness, enjoyment, satisfaction, attitude in this sector. Table 1 shows the key components and elements of forest biomass and bioenergy SCR with their descriptions.

Table 1 Key components and elements of forest biomass and bioenergy SCR with their descriptions

Resilience components and the descriptions
+ Forest Biomass and Bioenergy Supply Chain Resilience *"Capability of forest biomass and bioenergy SCN to return from sustained difficulties, for sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards".*
+ Barriers of Forest Biomass and Bioenergy Supply Chain Resilience *"Something material or immaterial that weakens or impedes the existence or improvement of the capability of forest biomass and bioenergy SC to return from sustained difficulties, for sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards".*
- Environmental Barriers of Forest Biomass and Bioenergy Supply Chain Resilience *"Something material or immaterial related to environment sphere that directly and indirectly weakens or impedes the performance quality in upstream, internal, and downstream levels of the forest biomass and bioenergy SC".*
- Economic Barriers of Forest Biomass and Bioenergy Supply Chain Resilience *"Something material or immaterial related to economy sphere that directly and indirectly weakens or impedes the performance quality in upstream, internal, and downstream levels of the forest biomass and bioenergy SC".*
- Social Barriers of Forest Biomass and Bioenergy Supply Chain Resilience *"Something material or immaterial related to society sphere that directly and indirectly weakens or impedes the performance quality in upstream, internal, and downstream levels of the forest biomass and bioenergy SC".*
- Technical Barriers of Forest Biomass and Bioenergy Supply Chain Resilience *"Something material or immaterial related to technology sphere that directly and indirectly weakens or impedes the performance quality in upstream, internal, and downstream levels of the forest biomass and bioenergy SC".*
- Strategic Barriers of Forest Biomass and Bioenergy Supply Chain Resilience *"Something material or immaterial related to strategy sphere that directly and indirectly weakens or impedes the performance quality in upstream, internal, and downstream levels of the forest biomass and bioenergy SC".*
+ Resilience Enablers of Forest Biomass and Bioenergy Supply Chain Resilience *"Something material or immaterial that promotes or empowers the existence or improvement of the capability of forest biomass and bioenergy SC to return from sustained difficulties, for sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards".*
- Environmental Enablers of Forest Biomass and Bioenergy Supply Chain Resilience *"Something material or immaterial related to environment sphere that directly and indirectly promotes or empowers the performance quality in upstream, internal, and downstream levels of the forest biomass and bioenergy SC".*
- Economic Enablers of Forest Biomass and Bioenergy Supply Chain Resilience *"Something material or immaterial related to economy sphere that directly and indirectly promotes or empowers the performance quality in upstream, internal, and downstream levels of the forest biomass and bioenergy SC".*
- Social Enablers of Forest Biomass and Bioenergy Supply Chain Resilience

"Something material or immaterial related to society sphere that directly and indirectly promotes or empowers the performance quality in upstream, internal, and downstream levels of the forest biomass and bioenergy SC".
- Technical Enablers of Forest Biomass and Bioenergy Supply Chain Resilience *"Something material or immaterial related to technology sphere that directly and indirectly promotes or empowers the performance quality in upstream, internal, and downstream levels of the forest biomass and bioenergy SC".*
- Strategic Enablers of Forest Biomass and Bioenergy Supply Chain Resilience *"Something material or immaterial related to strategy sphere that directly and indirectly promotes or empowers the performance quality in upstream, internal, and downstream levels of the forest biomass and bioenergy SC".*
+ Resilience Key Performance Indicators *"Key indicator that measures and optimizes the capability of forest biomass and bioenergy SC to return from sustained difficulties, for sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards".*
- Financial Performance (FP) *"Fulfillment of the SC functions based on the goals and plans by applying available inputs to achieve desirable outputs leading to high level of efficiency of the processes of attracting investments, maintaining assets, and segmenting and storing achievements to implement strategies within forest biomass and bioenergy SCN".*
- Forest Management Performance (FMP) *"Fulfillment of the SC functions based on the goals and plans by applying available inputs to achieve desirable outputs leading to high level of efficiency of the mensuration, processing, and improvement of a sustainable management of deforestation, afforestation, and reforestation, simultaneously based on a forest biomass and bioenergy SCN".*
- Marketing Performance (MP) *"Fulfillment of the SC functions based on the goals and plans by applying available inputs to achieve desirable outputs leading to high level of efficiency of the procedures, processes, flows and activities to create and develop relationships and interactions among the shareholders, stakeholders and customers within forest biomass and bioenergy SCN".*
- Customer Orientation Performance (COP) *"Fulfillment of the SC functions based on the goals and plans by applying available inputs to achieve desirable outputs leading to high level of efficiency of the procedures, processes, flows and activities by considering and with special attention to the needs and opinions of customers and feedbacks to create the positive and ongoing multidisciplinary relationships among suppliers, producers, distributors and consumers within forest biomass and bioenergy SCN".*
- Human Resource Performance (HRP) *"Fulfillment of the SC functions based on the goals and plans by applying available inputs to achieve desirable outputs leading to high level of efficiency of the recruiting and onboarding new hires, evaluating and firing inefficient staffs, constant research and training-learning processes, and updating the standards and policies related to the all individuals working within a forest biomass and bioenergy SCN".*
- Hardware System Performance (HSP) *"Fulfillment of the SC functions based on the goals and plans by applying available inputs to achieve desirable outputs leading to high efficiency level of the physical structure by determining, maintaining, evaluating and optimizing the equipment, flows, raw materials, goods and services within forest biomass and bioenergy SCN".*
- Software System Performance (SSP) *"Fulfillment of the SC functions based on the goals and plans by applying available inputs to achieve desirable outputs leading to high efficiency level of the cyberspace structure by determining, maintaining, evaluating and optimizing the applications, software skills, and all information and communication technologies within forest biomass and bioenergy SCN".*
+ Resilience Practices *"A factor influenced by constant research and experience and focused on a specific aspect that in form of a procedure regulates and strengthens the structuring and improvement of the capability of forest biomass and bioenergy SC to return from sustained difficulties, for sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards".*

- Adaptability *"Ability to regulate the goals, plans, activities with various situations to improve the capability of forest biomass and bioenergy SC to return from sustained difficulties, for sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards".*
- Anticipation *"Ability to realize or forestall the future needs, events, situations or actions in advance to improve the capability of forest biomass and bioenergy SC to return from sustained difficulties, for sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards".*
- Collaboration *"Ability to do joint activity of individuals, entities or organizations based on predetermined goals and plans to improve the capability of forest biomass and bioenergy SC to return from sustained difficulties, for sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards".*
- Commitment *"Ability to do activities in form of the agreement, promise or pledge based on predetermined goals and plans to improve the capability of forest biomass and bioenergy SC to return from sustained difficulties, for sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards"*.
- Flexibility *"Ability to change or reaction in the shortest time, at the lowest cost and with optimal performance to improve the capability of forest biomass and bioenergy SC to return from sustained difficulties, for sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards".*
- Information technology *"Ability to design, create and apply the technology for monitoring, collecting, evaluating, modifying and transmitting the information to improve the capability of forest biomass and bioenergy SC to return from sustained difficulties, for sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards".*
- Innovation *"Ability to design, create and apply something material or immaterial for the first time to improve the capability of forest biomass and bioenergy SC to return from sustained difficulties, for sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards".*
- Integration *"Ability to regulate, adjust or homogenize the whole physical and non-physical structures at various levels based on the goals, plans, activities to improve the capability of forest biomass and bioenergy SC to return from sustained difficulties, for sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards".*
- Leadership *"Ability to lead the individuals, entities, equipment, assets, investments, and strategies as inputs and outputs of network based on the goals and plans by considering changeability and uncertainty to improve the capability of forest biomass and bioenergy SC to return from sustained difficulties, for sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards".*
- Redundancy *"Ability to design, create and apply something material or immaterial as an alternative and in parallel with the main components to improve the capability of forest biomass and bioenergy SC to return from sustained difficulties, for*

sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards".
- Responsiveness *"Ability to respond and meet all kinds of demands and needs inside and outside the network in the shortest time, at the lowest cost and with optimal performance to improve the capability of forest biomass and bioenergy SC to return from sustained difficulties, for sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards".*
- Risk management *"Ability to systematically apply the management knowledge and experience for identifying, evaluating, prioritizing and optimizing all types of risk to improve the capability of forest biomass and bioenergy SC to return from sustained difficulties, for sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards".*
- Robustness *"Ability to tolerate the perturbations, fluctuations, and irregularities while maintaining or promoting efficiency level to improve the capability of forest biomass and bioenergy SC to return from sustained difficulties, for sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards".*
- Vulnerability *"Inability to regulate the capacity, potentials, characteristics and circumstances for resisting and reacting against the internal and external challenges to improve the capability of forest biomass and bioenergy SC to return from sustained difficulties, for sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards".*
+ Potential Stakeholders *"An individual, unit or organization in governmental and non-governmental levels that has a constant interaction with the forest biomass and bioenergy SCN and can either affect or be affected by the relevant goals, plans and activities".*
- Communities *"Communities that have a constant interaction with the forest biomass and bioenergy SCN and can either affect or be affected by the relevant goals, plans and activities".*
- Customers *"Customers that have a constant interaction with the forest biomass and bioenergy SCN and can either affect or be affected by the relevant goals, plans and activities".*
- Distributors *"Distributors that have a constant interaction with the forest biomass and bioenergy SCN and can either affect or be affected by the relevant goals, plans and activities".*
- Employees *"Employees that have a constant interaction with the forest biomass and bioenergy SCN and can either affect or be affected by the relevant goals, plans and activities".*
- Governments *"Governments that have a constant interaction with the forest biomass and bioenergy SCN and can either affect or be affected by the relevant goals, plans and activities".*
- Investors *"Investors that have a constant interaction with the forest biomass and bioenergy SCN and can either affect or be affected by the relevant goals, plans and activities".*
- Suppliers

"Suppliers that have a constant interaction with the forest biomass and bioenergy SCN and can either affect or be affected by the relevant goals, plans and activities".

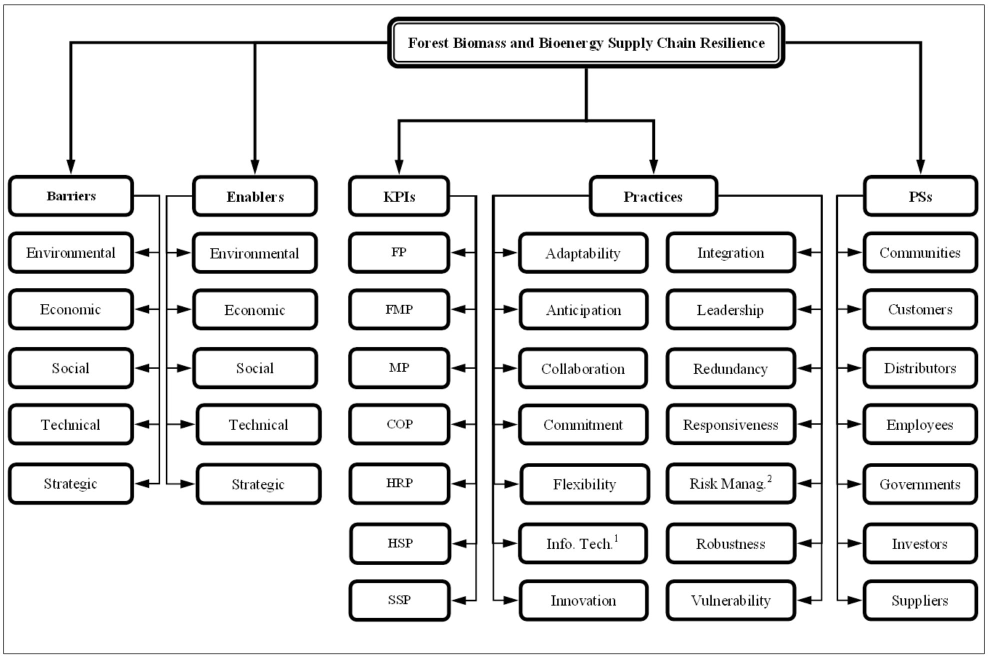
2.6. Confirmatory factor analysis (CFA)

To investigate the acceptance or non-acceptance of interactions among the different types and levels of variables indicated by the hypotheses, we used a confirmatory factor analysis (CFA). The CFA can be applied as an efficient and flexible methodology (Spearman, 1961). Indeed, the CFA is usually applied for evaluating the infrastructure of the proposed model to detect whether the relationships between variables are justified or unjustified in form of an underlying structure (Spearman, 1961). It has so many specifications in terms of performance such as high variety in application, ease of use in different software, applicability as a combined approach, developing an analytical model with a set of variables and hypotheses as well as measuring the interactions within the system structure in a particular perceptual scope (Thompson, 2004). Therefore, CFA can be considered as an efficient methodology to investigate the hypotheses related to the variables and interactions among them to reach an unfathomable comprehension on the competence of the structure of proposed model (Thompson, 2004).

2.7. Designing a third order CFA model based on research hypotheses and questions

In this research study, the conceptual decision-making model is designed in form of a third order CFA pattern based on the determined latent and observable variables. The third order CFA is an appropriate methodology for the modeling study in which the latent variables have three levels that the only first level variables are measured by observable variables. In fact, third order CFA model is used when the first order variables are explained by the second order variables as well as the second order variables are explained by the third order variables. The proposed model is designed for the first time in this field. In this line, forest biomass and bioenergy SCR is considered as a third order latent variable. Also, the resilience barriers, enablers, KPIs, practices, and potential stakeholders are considered as second order variables. Moreover, the subsets of the second order variables are considered as first order variables. As obvious or observable variables, three questions are designed to evaluate the uncertainty, quantity or severity, and quality or intensity levels of each of the first order variables. the questions of the questionnaire are incorporated in the appendix section. Figure 1 indicates the proposed model. All interactions, in form of arrows in the model, among the latent variables are considered as hypotheses, in which case, there are 43 hypotheses for investigating. Table 2 shows the research hypotheses. It should be noted that the reason for the lack of relevance of the second order variables with each other is due to the structure of the third order CFA model. Indeed, if they are included in the model, the validity and reliability of the model will be reduced which has been practically reviewed.

2.8. Validation of the third order CFA model



[1] Information Technology; [2] Risk Management

Figure 1 Proposed decision-making model

Table 2 Research hypotheses

Main hypotheses and sub-hypotheses
H1. Resilience barriers best-fit forest biomass and bioenergy supply chain resilience. **H1a.** Environmental barriers best-fit resilience barriers. **H1b.** Economic barriers best-fit resilience barriers. **H1c.** Social barriers best-fit resilience barriers. **H1d.** Technical barriers best-fit resilience barriers. **H1e.** Strategic barriers best-fit resilience barriers.
H1. Resilience enabler best-fit forest biomass and bioenergy supply chain resilience. **H1a.** Environmental enablers best-fit resilience barriers. **H1b.** Economic enabler best-fit resilience barriers. **H1c.** Social enablers best-fit resilience barriers. **H1d.** Technical enablers best-fit resilience barriers. **H1e.** Strategic enablers best-fit resilience barriers.
H3. Resilience key performance indicators best-fit forest biomass and bioenergy supply chain resilience. **H3a.** Financial performance best-fit resilience key performance indicators. **H3b.** Forest management performance best-fit resilience key performance indicators. **H3c.** Marketing performance best-fit resilience key performance indicators. **H3d.** Customer orientation performance best-fit resilience key performance indicators. **H3e.** Human resource performance best-fit resilience key performance indicators. **H3f.** Hardware system performance best-fit resilience key performance indicators. **H3g.** Software system performance best-fit resilience key performance indicators.
H4. Resilience practices best-fit forest biomass and bioenergy supply chain resilience. **H4a.** Adaptability best-fit resilience practices. **H4b.** Anticipation best-fit resilience practices. **H4c.** Collaboration best-fit resilience practices. **H4d.** Commitment best-fit resilience practices. **H4e.** Flexibility best-fit resilience practices. **H4f.** Information technology best-fit resilience practices. **H4g.** Innovation best-fit resilience practices. **H4h.** Integration best-fit resilience practices. **H4i.** Leadership best-fit resilience practices. **H4j.** Redundancy best-fit resilience practices. **H4k.** Responsiveness best-fit resilience practices. **H4l.** Risk management best-fit resilience practices. **H4m.** Robustness best-fit resilience practices. **H4n.** Vulnerability best-fit resilience practices.
H5. Potential stakeholders best-fit forest biomass and bioenergy supply chain resilience. **H5a.** Communities best-fit potential stakeholders. **H5b.** Customers best-fit potential stakeholders. **H5c.** Distributors best-fit potential stakeholders. **H5d.** Employees best-fit potential stakeholders. **H5e.** Governments best-fit potential stakeholders. **H5f.** Investors best-fit potential stakeholders. **H5g.** Suppliers best-fit potential stakeholders.

Validation of the proposed model based on the third order CFA methodology is carried out by the partial least squares (PLS) technique in SmartPLS3 software (Cieciuch, Davidov, Vecchione, & Schwartz, 2014; Ramayah, Cheah, Chuah, Ting, & Memon, 2018). The PLS is a non-parametric technique based on regression procedures (Ramayah et al., 2018). In mentioned technique and software, there is low sensitivity to the sample size and data normality, which are their significant positive features (Ramayah et al., 2018). Therefore, reaching to the reliable results by adapting to the limitations and complexities of research can be accessible.

The two main indicators are considered to accept or reject the hypotheses which are factor loading and path coefficient. The acceptable values for factor loading and path coefficient are higher than 0.5 and 0.3, respectively.

2.9. Questionnaire

In this study, Data were collected by circulating a questionnaire to the small-sized and medium-sized forest biomass and bioenergy industries. These industries are continuously active at different levels in the field of supply chain of forest products, converting material into biomass to produce modern bioenergy. The small-sized industries often operate in the field of biomass production by harvesting trees and collecting wood waste in the dense forests. These industries are closely linked to bio-production industries and interact with each other in the form of a SCN. The medium-sized industries often operate in the field of bioenergy and bioproducts by supplying forest biomass as raw materials, producing the bioenergy and bioproducts, and providing them to power plants and relevant companies. The reason for choosing these industries as a set is their cooperation in the form of forest biomass and bioenergy SCN. Taking advantage of the details of this connection and bilateral cooperation can be useful in answering many questions and meeting necessary needs. To increase the size of the statistical population, the viewpoints of researchers in the academic environment have also been used so that both theoretical and practical dimensions are effective in the results achieved. In this line, questionnaire was designed to determine the acceptance or non-acceptance of the hypotheses including the interactions among all components and the entire resilience capability for the forest biomass and bioenergy SC. Second, the questionnaire designed to assess the experimental and educational reputation of the respondents as experts in small-sized and medium-sized forest biomass and bioenergy industries as well as the independent researchers working on the relevant issues. To obtain reliable data, the questionnaires were distributed, completed, and received in person. The first-type questionnaire includes the 5-point Likert scale to be comfortable for responding and to comply with the standards. The three main questions of the questionnaire designed to evaluate each hypothesis are:

- Uncertainty level of X-component significantly impacts on the Y-component of forest biomass and bioenergy SC.
- Quantity or severity of X-component significantly impacts on the Y-component of forest biomass and bioenergy SC.
- Quality or intensity of X-component significantly impacts on the Y-component of forest biomass and bioenergy SC.

* X-components and Y-components are in different levels.

Evaluation of the appropriateness of the sample size is carried out by the KMO measure of sampling adequacy test and Bartlett’s Test of Sphericity. To analyze the reliability level of the data and questionnaires the Cronbach's alpha and composite reliability technique and to analyze the validity the CFA methodology are used. In addition, the quality of the proposed conceptual decision-making model will be discussed in detail in the results section.

3. Results

Table 3 shows the analysis of the number of questionnaires distributed and received. Frequency percentages indicate the efficiency and success in the data collection process. Out of 450 considered questionnaires, 381 usable questionnaires were collected, which includes about 85% of all questionnaires. Also, the statistical characteristics of respondents in small-sized and medium-sized industries working on forest biomass and bioenergy as well as the independent researchers incorporated in Table 4, 5, and 6 indicating the high level of the respondents in terms of education and experience. Table 4, 5, and 6 shows the high levels of education and work experience of all the respondents to the questionnaire.

Based on the Table 7, the value of KMO measure of sampling adequacy test obtained about 0.915 (greater than 0.7 is acceptable), that in this case, the sample size is significantly desirable for implementing the methodology on the proposed model. In addition, on the Bartlett’s Test of Sphericity, the value of normed chi-square (the ratio of chi-square to degree of freedom) is 4.199 (less than five is acceptable), that in this case, it is desirable. Moreover, the significance level obtained about zero, so that the null hypothesis is rejected and the efficiency of third order CFA methodology is approved.

Table 3 Analysis of the questionnaires

Type of Industries	All Questionnaires	Received Questionnaires	Frequency Percentage
All Experts	450	381	85
Small-sized Industries	180	156	87
Medium-sized Industries	120	99	83
Researchers	150	126	84

Table 4 Statistical characteristics of respondents in small-sized industries

Characteristics	Frequency	Percentage frequency
Level of education		
Lower than bachelor's degree	9	6
Bachelor's degree	48	31
Master's degree	84	54
PhD degree	15	9
Level of experience		
Less than 5 years	27	17
Between 5 to 10 years	63	40
Between 10 to 15 years	45	29
Between 15 to 20 years	21	14
Between 20 to 25 years	-	-
More than 25 years	-	-

Table 5 Statistical characteristics of respondents in medium-sized industries

Characteristics	Frequency	Percentage frequency
Level of education		
Lower than bachelor's degree	12	12
Bachelor's degree	30	30
Master's degree	39	40
PhD degree	18	18
Level of experience		
Less than 5 years	6	6
Between 5 to 10 years	48	49
Between 10 to 15 years	24	24
Between 15 to 20 years	12	12
Between 20 to 25 years	9	9
More than 25 years	-	-

Table 6 Statistical characteristics of respondents as researchers

Characteristics	Frequency	Percentage frequency
Level of education		
Lower than bachelor's degree	-	-
Bachelor's degree	-	-
Master's degree	105	83
PhD degree	21	17
Level of experience		
Less than 5 years	-	-
Between 5 to 10 years	15	12
Between 10 to 15 years	78	62
Between 15 to 20 years	33	26
Between 20 to 25 years	-	-
More than 25 years	-	-

Table 7 Results of Bartlett's Test of Sphericity and KMO measure of sampling adequacy test

Tests		Values
KMO measure of sampling adequacy test		0.915
Bartlett's Test of Sphericity	Chi-square approximation	27047.775
	Degree of freedom	6441
	Significance level	0.000

Table 8 indicates the results of reliability tests including the Cronbach's alpha and composite reliability values. According to the results, all the cronbach's alpha values are more than 0.6 for first order variables. In addition, all the composite reliability values are more than 0.7. In general, cronbach's alpha and composite reliability values for the whole questionnaires are 0.975 and 0.976, respectively. The total values obtained indicate the high reliability of the questionnaires at various levels. Moreover, the number of variables, means and standard deviations are incorporated in Table 8.

Table 8 Reliability of questionnaires and data

FOVs*	Questions	Means	Standard deviations	Cronbach's alpha values	Composite reliability
V1	3	4.227	0.730	0.620	0.796
V2	3	0.400	0.691	0.734	0.850
V3	3	4.229	0.721	0.688	0.827
V4	3	4.002	0.764	0.711	0.839
V5	3	4.374	0.660	0.688	0.827
V6	3	4.206	0.730	0.749	0.857
V7	3	4.401	0.687	0.734	0.850
V8	3	4.231	0.707	0.729	0.847

V9	3	4.021	0.745	0.720	0.843
V10	3	4.400	0.672	0.742	0.854
V11	3	4.017	0.742	0.742	0.853
V12	3	4.374	0.666	0.721	0.843
V13	3	4.330	0.678	0.709	0.838
V14	3	4.342	0.676	0.743	0.855
V15	3	4.339	0.689	0.724	0.845
V16	3	4.031	0.741	0.667	0.818
V17	3	4.328	0.669	0.731	0.849
V18	3	4.376	0.658	0.709	0.837
V19	3	4.283	0.663	0.699	0.833
V20	3	4.288	0.684	0.805	0.885
V21	3	4.434	0.624	0.704	0.836
V22	3	4.360	0.640	0.677	0.823
V23	3	4.321	0.647	0.664	0.817
V24	3	4.336	0.667	0.688	0.827
V25	3	4.362	0.639	0.669	0.820
V26	3	4.339	0.633	0.694	0.831
V27	3	4.294	0.675	0.705	0.836
V28	3	4.370	0.651	0.772	0.868
V29	3	4.360	0.651	0.684	0.826
V30	3	4.228	0.691	0.694	0.830
V31	3	4.220	0.695	0.689	0.828
V32	3	4.292	0.680	0.785	0.875
V33	3	4.357	0.631	0.650	0.805
V34	3	4.110	0.728	0.648	0.809
V35	3	4.315	0.648	0.623	0.799
V36	3	4.367	0.648	0.722	0.844
V37	3	4.388	0.646	0.659	0.815
V38	3	4.158	0.713	0.666	0.818
All variables	114	4.284	0.681	0.975	0.976

*First Order Variables

Given the fact that CFA is the best methodology to evaluate the validity of the questionnaires and data, it is used in this research to increase the level of the results. Table 9 indicates the results of validity test. In this line, all the factor loadings achieved by implementation of the model are greater than 0.5, so that validity of the questionnaires and data is approved.

Table 9 Validity of questionnaires and data

Questions	Factor loadings	Questions	Factor loadings	Questions	Factor loadings
1	0.616	39	0.803	77	0.749
2	0.827	40	0.825	78	0.804
3	0.802	41	0.797	79	0.787
4	0.741	42	0.819	80	0.803
5	0.844	43	0.774	81	0.788
6	0.838	44	0.802	82	0.833
7	0.693	45	0.833	83	0.794
8	0.832	46	0.733	84	0.859
9	0.823	47	0.803	85	0.737
10	0.848	48	0.787	86	0.766
11	0.743	49	0.794	87	0.841
12	0.796	50	0.800	88	0.758
13	0.794	51	0.827	89	0.810
14	0.802	52	0.782	90	0.794
15	0.756	53	0.793	91	0.743
16	0.787	54	0.810	92	0.804
17	0.843	55	0.805	93	0.807
18	0.818	56	0.787	94	0.851
19	0.718	57	0.779	95	0.844
20	0.860	58	0.812	96	0.816
21	0.841	59	0.869	97	0.836
22	0.776	60	0.865	98	0.835
23	0.787	61	0.800	99	0.597
24	0.853	62	0.747	100	0.818
25	0.763	63	0.830	101	0.737
26	0.851	64	0.806	102	0.740
27	0.786	65	0.677	103	0.768
28	0.808	66	0.849	104	0.745
29	0.817	67	0.767	105	0.753
30	0.814	68	0.777	106	0.809
31	0.815	69	0.775	107	0.782
32	0.818	70	0.781	108	0.814
33	0.803	71	0.741	109	0.770
34	0.800	72	0.830	110	0.772
35	0.803	73	0.764	111	0.773

36	0.801	74	0.765	112	0.771
37	0.776	75	0.800	113	0.752
38	0.807	76	0.810	114	0.801

Given the fact that there are 43 paths in the proposed model, so in this case 43 hypotheses should be considered to accept or reject the interactions among the first, second, and third order variables as latent ones. In this line, Table 10 indicates the path coefficients analysis. Based on the results, all the path coefficients are desirable so that the entire relevant hypotheses are accepted. It indicates that the mentioned variables have potential interactions with each other. Therefore, the whole structure of the model is efficient.

Table 10 Results of path analysis analysis

Paths (hypotheses)	**Coefficients**	**Statuses**
Forest Biomass and Bioenergy Supply Chain Resilience → Resilience Barriers	0.890	Accepted
Forest Biomass and Bioenergy Supply Chain Resilience → Resilience Enablers	0.928	Accepted
Forest Biomass and Bioenergy Supply Chain Resilience → Resilience Key Performance Indicators	0.913	Accepted
Forest Biomass and Bioenergy Supply Chain Resilience → Resilience Practices	0.946	Accepted
Forest Biomass and Bioenergy Supply Chain Resilience → Potential Stakeholders	0.888	Accepted
Resilience Barriers → Environmental Barriers	0.723	Accepted
Resilience Barriers → Economic Barriers	0.806	Accepted
Resilience Barriers →Social Barriers	0.691	Accepted
Resilience Barriers → Technical Barriers	0.701	Accepted
Resilience Barriers → Strategic Barriers	0.760	Accepted
Resilience Enablers → Environmental Enablers	0.806	Accepted
Resilience Enablers → Economic Enablers	0.779	Accepted
Resilience Enablers →Social Enablers	0.755	Accepted
Resilience Enablers → Technical Enablers	0.657	Accepted
Resilience Enablers → Strategic Enablers	0.829	Accepted
Resilience Key Performance Indicators → Financial Performance	0.611	Accepted
Resilience Key Performance Indicators → Forest Management Performance	0.787	Accepted
Resilience Key Performance Indicators → Marketing Performance	0.736	Accepted
Resilience Key Performance Indicators → Customer Orientation Performance	0.672	Accepted
Resilience Key Performance Indicators → Human Resource Performance	0.787	Accepted
Resilience Key Performance Indicators → Hardware System Performance	0.649	Accepted
Resilience Key Performance Indicators → Software System Performance	0.757	Accepted
Resilience Practices → Adaptability	0.696	Accepted
Resilience Practices → Anticipation	0.675	Accepted
Resilience Practices → Collaboration	0.703	Accepted
Resilience Practices → Commitment	0.694	Accepted
Resilience Practices → Flexibility	0.679	Accepted

Resilience Practices → Information technology	0.704	Accepted
Resilience Practices → Innovation	0.718	Accepted
Resilience Practices → Integration	0.718	Accepted
Resilience Practices → Leadership	0.642	Accepted
Resilience Practices → Redundancy	0.741	Accepted
Resilience Practices → Responsiveness	0.710	Accepted
Resilience Practices → Risk management	0.746	Accepted
Resilience Practices → Robustness	0.664	Accepted
Resilience Practices → Vulnerability	0.645	Accepted
Potential Stakeholders → Communities	0.768	Accepted
Potential Stakeholders → Customers	0.636	Accepted
Potential Stakeholders → Distributors	0.536	Accepted
Potential Stakeholders → Employees	0.638	Accepted
Potential Stakeholders → Governments	0.694	Accepted
Potential Stakeholders → Investors	0.651	Accepted
Potential Stakeholders → Suppliers	0.674	Accepted

Qualitative evaluation of the model requires various and reliable tests. The indices of determination coefficient (R-Squared or R^2), cross validation redundancy (CV Red or Q^2) to evaluate the quality of the structural model, cross validation communality (CV Com) to evaluate the quality of the measurement model, effect size criteria (F-square or F^2) to evaluate the effect between the variables, and goodness of fit (GOF) to evaluate the quality of the whole model were calculated. Table 11 indicates the values of R^2, CV Com, CV Red or Q^2, and GOF. R^2 is one of the important indices to evaluate the endogenous latent variables in a model. In fact, it indicates what percentage of changes in endogenous variable is caused by exogenous variable. In this line, the values of 0.19, 0.33, and 0.67 can be considered as weak, moderate, and significant values, respectively. Based on the results, all the values are at the appropriate level.

The quality of measurement model is generally evaluated by the CV Red indicator. According to the results in Table 11, all the values obtained are positive, which indicates the significant quality of the measurement model. Also, the quality of structural model is generally evaluated by the CV Com indicator. In this line, all values associated with the CV Com indicator are positive. Therefore, the quality of structural model is also appropriate in this research study.

To measuring the whole conceptual decision-making model in form of the third order CFA methodology, the GOF indicator is applied evaluating the features of both measurement and structural models. It is calculated from the following equation:

$$GOF = \sqrt{\overline{Communality} \times \overline{R^2}} \quad \text{..................(1)}$$

The value can be between zero (very low) and one (very high). Based on the results, the value of GOF indicator obtained about 0.566, which indicates the very appropriate and significant quality of the proposed model.

Table 12 shows the values of F^2 for the proposed model. As mentioned, it describes the amount of effect the exogenous variable on the endogenous variable. Based on the results, all values illustrate the very strong effects which in turn imply high efficiency of the proposed model.

Table 11 Evaluation indexes of the quality of decision-making model

Variables	**Evaluation indexes**			
	R^2	**CV Red**	**CV Com**	**GOF**
+ Resilience Barriers	0.792	0.261	0.239	-
- Environmental Barriers	0.522	0.291	0.176	-
- Economic Barriers	0.650	0.419	0.314	-
- Social Barriers	0.477	0.289	0.252	-
- Technical Barriers	0.492	0.303	0.281	-
- Strategic Barriers	0.578	0.349	0.241	-
+ Resilience Enablers	0.862	0.326	0.305	-
- Environmental Enablers	0.650	0.422	0.332	-
- Economic Enablers	0.606	0.384	0.320	-
- Social Enablers	0.570	0.356	0.304	-
- Technical Enablers	0.432	0.264	0.289	-
- Strategic Enablers	0.688	0.441	0.320	-
+ Resilience Key Performance Indicators	0.833	0.269	0.269	-
- Financial Performance	0.373	0.234	0.318	-
- Forest Management Performance	0.619	0.385	0.286	-
- Marketing Performance	0.542	0.331	0.271	-
- Customer Orientation Performance	0.452	0.288	0.324	-
- Human Resource Performance	0.620	0.388	0.294	-
- Hardware System Performance	0.421	0.241	0.216	-
- Software System Performance	0.572	0.362	0.303	-
+ Resilience Practices	0.894	0.267	0.275	-
- Adaptability	0.485	0.298	0.270	-
- Anticipation	0.455	0.276	0.256	-
- Collaboration	0.495	0.349	0.429	-
- Commitment	0.482	0.292	0.266	-
- Flexibility	0.461	0.272	0.243	-
- Information Technology	0.496	0.286	0.210	-
- Innovation	0.515	0.307	0.245	-
- Integration	0.516	0.301	0.219	-
- Leadership	0.412	0.247	0.252	-
- Redundancy	0.549	0.335	0.264	-
- Responsiveness	0.503	0.336	0.369	-
- Risk Management	0.557	0.330	0.240	-
- Robustness	0.441	0.263	0.249	-

- Vulnerability	0.415	0.246	0.246	-
+ Potential Stakeholders	0.788	0.207	0.204	-
- Communities	0.590	0.406	0.392	-
- Customers	0.405	0.227	0.213	-
- Distributors	0.287	0.161	0.192	-
- Employees	0.406	0.226	0.161	-
- Governments	0.482	0.303	0.289	-
- Investors	0.423	0.245	0.204	-
- Suppliers	0.454	0.267	0.213	-
+ Forest Biomass and Bioenergy Supply Chain Resilience	0.000	0.000	0.252	-
Whole model	-	-	-	0.566

Table 12 Values of F Square or F^2

From	To	F^2
+ Forest Biomass and Bioenergy Supply Chain Resilience	- Resilience Barriers	3.811
	- Resilience Enablers	6.223
	- Resilience Key Performance Indicators	4.976
	- Resilience Practices	8.457
	- Potential Stakeholders	3.716
+ Resilience Barriers	- Environmental Barriers	1.093
	- Economic Barriers	1.854
	- Social Barriers	0.913
	- Technical Barriers	0.967
	- Strategic Barriers	1.370
+ Resilience Enablers	- Environmental Enablers	1.859
	- Economic Enablers	1.539
	- Social Enablers	1.326
	- Technical Enablers	0.761
	- Strategic Enablers	2.204
+ Resilience Key Performance Indicators	- Financial Performance	0.595
	- Forest Management Performance	1.625
	- Marketing Performance	1.182
	- Customer Orientation Performance	0.824
	- Human Resource Performance	1.630
	- Hardware System Performance	0.727
	- Software System Performance	1.339
+ Resilience Practices	- Adaptability	0.942

	- Anticipation	0.836
	- Collaboration	0.979
	- Commitment	0.931
	- Flexibility	0.855
	- Information Technology	0.984
	- Innovation	1.063
	- Integration	1.066
	- Leadership	0.702
	- Redundancy	1.217
	- Responsiveness	1.014
	- Risk Management	1.258
	- Robustness	0.789
	- Vulnerability	0.711
+ Potential Stakeholders	- Communities	1.437
	- Customers	0.681
	- Distributors	0.402
	- Employees	0.685
	- Governments	0.930
	- Investors	0.734
	- Suppliers	0.832

Consequently, the nature of this research study and its results can be cited as a new and updated source because it is one of the first works in the field of forest biomass and bioenergy SCR. Therefore, researchers and managers can reach to inclusive comprehension on the significance of resilience capability in this field.

4. Discussion

The main objective of the proposed model is creating resilient forest biomass and bioenergy SC. To this end, the effective interactions should have been investigated leading to clear understanding on impacts of the components on the forest biomass and bioenergy SCR in form of a decision-making model. In this study, the components affecting resilience, their stratification and the relationships between them are investigated.

There are other methodologies, as alternatives, to conduct this research work such as exploratory factor analysis (EFA) and regression analysis (RA) having disadvantages compared to the method used. The EFA is suitable when a pre-designed model and main variables are not available (Fabrigar & Wegener, 2011), while in this research the model and hypotheses are pre-designed and determined. Basically, RA considers and evaluates the relationships between a dependent variable and several independent variables (Draper & Smith, 1998), while in this research, the relationships and correlations between several dependent and independent variables are evaluated in pairs. Therefore, the CFA as most efficient methodology is and effective and efficient tool to obtain reliable results in this way. The reason for using third-order modeling is the existence of three layers among the main components of the research.

4.1. Resilience barriers of the forest biomass and bioenergy SC

Resilience barriers play significant role in limiting the opportunities and capabilities to have resilient system structure within forest biomass and bioenergy SCN. In this research, the barriers were divided into five categories which are environmental, economic, social, technical, and strategic barriers. Based on the results, the path coefficient between the "resilience barriers" and "forest biomass and bioenergy supply chain resilience" is significant (0.890). It proves that by eliminating these barriers, a resilient structure can be developed for forest biomass and bioenergy SC.

4.1.1. Environmental barriers

Environmental aspect of a businesses such as SC sector covers a widespread range of challenges such as environmental uncertainty and pressure (Dashtpeyma & Ghodsi, 2021; Fattahi, Govindan, & Farhadkhani, 2021; Honig & Samuelsson, 2021). Due to the increase in unexpected events including natural and man-made disasters, when and how to deal with this type of barriers play key roles in improving the performance level of forest biomass and bioenergy industries in small, medium and large sizes (Fattahi et al., 2021). Hence, adapting to dynamic and uncertain environments significantly impact on the success or failure rates in such a business (Dashtpeyma & Ghodsi, 2021; Honig & Samuelsson, 2021; Lattimore, Smith, Titus, Stupak, & Egnell, 2009). Environmental barriers shake the level of resilience in this scope. These barriers affect the willingness of investors to set up and run the processes and flows that is mostly due to legal and political weaknesses (Dashtpeyma & Ghodsi, 2021; Mohammadi, Safyari, & Khosravi, 2020). For the sake of the present and forthcoming changes in the environment such as climate changes and potentials, effectively dealing with the environmental barriers can increase resilience level which in turn determines the success level of forest biomass and bioenergy level in various aspects. Based on the results, the path coefficient between the "environmental barriers" and "resilience barriers" is significant (0.723). It proves that eliminating these barriers play an important role in dealing with the resilience barriers leading to development of resilient structure for forest biomass and bioenergy SC.

4.1.2. Economic barriers

Considering the economic aspect of the biomass and bioenergy industries in developed and developing countries is of great importance as a topic or research gap (Akhtari, Sowlati, & Day, 2014; Dashtpeyma & Ghodsi, 2021). In this line, economic barriers can play important role in constraining different sizes of SCs on forest biomass and bioenergy sector from expanding market share and internationalizing (Akhtari et al., 2014; Dashtpeyma & Ghodsi, 2021; Lee & Chung, 2018). In fact, incompetent economic inputs and outputs may mitigate efficiency and performance of the SCs as well as shrinking the sphere of influence of such businesses in the competitive markets. In addition, economic barriers have significant role in challenging the level of cooperation in network by determining the inputs and outputs considered by stakeholders and shareholders (Buttoud, Kouplevatskaya-Buttoud, Slee, & Weiss, 2011; Dashtpeyma & Ghodsi, 2021; Draskovic, Jovovic, & Rabe, 2020). Therefore, when and how to access to the economic opportunities and advantages are the most important issues during processes and flows leading to economic quality and quantity levels for small, medium and large sizes of the relevant industries (Dashtpeyma & Ghodsi, 2021; M. Rahman, Akter, Odunukan, & Haque, 2020). Based on the results, the path coefficient between the "economic barriers" and "resilience barriers" is significant (0.806). It proves that eliminating these barriers play an important role in dealing with the resilience barriers leading to development of resilient structure for forest biomass and bioenergy SC.

4.1.3. Social barriers

These barriers in forms of the internal and external factors that put negative challenges in the way so that doing activities based on the desired plans and goals becomes difficult. Social barriers have a significant impact on the growth of forest biomass and bioenergy SCN, in a way that with the fluctuations of potentials and needs in the social sphere, the rate of profit and loss also changes (Dashtpeyma & Ghodsi, 2021; Galik, Benedum, Kauffman, & Becker, 2021). These type of barriers may include language, social norms and practices as well as staff skills' training and customers' educating and informing (Mendy, Rahman, & Bal, 2020). Therefore, efficiently managing and dealing with the social barriers not only reduce the social risks but also increase the resilience capability of the forest biomass and bioenergy SCNs in uncertain marketplaces. Based on the results, the path coefficient between the "social barriers" and "resilience barriers" is significant (0.691). It proves that eliminating these barriers play an important role in dealing with the resilience barriers leading to development of resilient structure for forest biomass and bioenergy SC.

4.1.4. Technical barriers

One of the most important tools for modernizing the forest biomass and bioenergy SCN is dynamic and efficient technology. The existence of technical shortages and limitations can lead to a lack of the constant development of this type of SCs (Dashtpeyma & Ghodsi, 2021; Zahraee, Shiwakoti, & Stasinopoulos, 2022). Technical barriers may induce the costs of the main SC functions. Therefore, it can be said that these type of barriers can affect the quantity and quality of domestic and foreign investments (Ghodsi, 2020). Due to the rapid advancement of technology in line with the needs and potentials, dealing with technical barriers can increase resilience level of the forest biomass and bioenergy SC which in turn increases the market share and size of the SCN as well as the levels of nature friendliness, satisfaction, and profitability. Based on the results, the path coefficient between the "technical barriers" and "resilience barriers" is significant (0.701). It proves that eliminating these barriers play an important role in dealing with the resilience barriers leading to development of resilient structure for forest biomass and bioenergy SC.

4.1.5. Strategic barriers

Strategic barriers significantly limit the ability of managers to accurately target as well as successfully conducting or completing the plans. These type of barriers affect the risks level during the operations, managerial feedbacks, and knowledge management (Zerbino, Aloini, Dulmin, & Mininno, 2018). Also, they can negatively affect the management of investment, costs and revenues by increasing the unbalanced uncertainty (Phruksaphanrat & Borisutiyanee, 2019). Given the fact that decision-making processes can be impacted by strategies, dealing with strategic barriers can increase resilience level of forest biomass and bioenergy SC which in turn reduces the negative impact of uncertainty as well as increases the efficiency level (Dashtpeyma & Ghodsi, 2021). Based on the results, the path coefficient between the "strategic barriers" and "resilience barriers" is significant (0.760). It proves that eliminating these barriers play an important role in dealing with the resilience barriers leading to development of resilient structure for forest biomass and bioenergy SC.

4.2. Resilience enablers of the forest biomass and bioenergy SC

Resilience enablers play significant role in promoting the potencies to have resilient system structure within forest biomass and bioenergy SCN. In this research, the enablers were divided into five categories which are environmental, economic, social, technical, and strategic enablers. Based on the results, the path coefficient between the "resilience enablers" and "forest biomass and bioenergy supply chain resilience" is significant (0.928). It proves that by improving these enablers, a resilient structure can be developed for forest biomass and bioenergy SC.

4.2.1. Environmental enablers

Environmental enablers can pave the way to dealing with uncertain environmental situations leading to the sustainable development of forest-based industries (Dashtpeyma & Ghodsi, 2021; She, Chung, & Han, 2019). In fact, empower the system structure of the relevant businesses causes the using of environmental features in normal and critical levels does not fluctuate. The environmental enablers are the drivers of forest biomass and bioenergy SCN expansion and growth (Dashtpeyma & Ghodsi, 2021). These enablers provide the circumstances for the decision-making process between owners and investors of the forest-based industries for leading to the continuous utilization of environmental potentials, which in turn shifts the local position of such businesses towards global position (Picciano, Aguilar, Burtraw, & Mirzaee, 2022). Therefore, optimal use and upgrade of environmental enablers can improve managerial resilience of forest biomass and bioenergy SC to deal with the environmental uncertainties occurring simultaneously with the exploitation of natural resources and to increases the optimal performance quality during various events. Based on the results, the path coefficient between the "environmental enablers" and "resilience enablers" is significant (0.806). It proves that improving these enablers play an important role in advancing the resilience enablers leading to development of resilient structure for forest biomass and bioenergy SC.

4.2.2. Economic enablers

Economic enablers affect the competitive and commercial-scale production and consumption levels in all the businesses (Milani, Kiani, & McNaughton, 2020). It is due to the impact of these type of enablers in lowering the levelized cost as well as improving the financial infrastructure based on the economic goals, plans, and activities (Milani et al., 2020). Also, economic enablers help the communities manage potential risks leading to the local and global instability and conflict in businesses such as forest biomass and bioenergy SCs (Dashtpeyma & Ghodsi, 2021; Yannakogeorgos, 2021). Hence, improvement of the economic enablers can significantly optimize the resilience capability of forest biomass and bioenergy SCN to deal with the short-term, medium-term, and long-term economic crises as well as turning the local SCN into the global SCN. Based on the results, the path coefficient between the "economic enablers" and "resilience enablers" is significant (0.779). It proves that improving these enablers play an important role in advancing the resilience enablers leading to development of resilient structure for forest biomass and bioenergy SC.

4.2.3. Social enablers

In recent years, social enablers are considered as vital conditions/precursors for prosperous forest biomass and bioenergy SC targeting and planning processes by upgrading the commitment and communication levels, and also balanced and empowered implementation structure (Dashtpeyma & Ghodsi, 2021; He & Turner, 2021) In addition, these enablers considerably impact on the sustainability of emerging all the businesses (Jamwal, Agrawal, Sharma, Kumar, & Kumar, 2021). Indeed, social enablers play an important role in balancing the development of the forest biomass and bioenergy SCN with the potentials and needs of society by facilitating an efficient relationship between them. Based on the results, the path coefficient between the "social enablers" and "resilience enablers" is significant (0.755). It proves that improving these enablers play an important role in advancing the resilience enablers leading to development of resilient structure for forest biomass and bioenergy SC.

4.2.4. Technical enablers

Technical enablers are potent tools in improving the infrastructure of the forest biomass and bioenergy SCN and increasing the dynamism and stability of the upstream, internal, and downstream processes and flows (Dashtpeyma & Ghodsi, 2021; Fahriye Enda & Karaosmanoglu, 2021). Given the fact that the importance of software applications in commerce, adaptability between the demand for goods and services and technical capacity, and connection between the physical environment and the digital overlay is increasing day by day, so that determination and optimization of the technical enablers for a business network cause a undeniable advance in performance quality (Dashtpeyma & Ghodsi, 2021; Lugmayr, 2010). Based on the results, the path coefficient between the "technical enablers" and "resilience enablers" is significant (0.657). It proves that improving these enablers play an important role in advancing the resilience enablers leading to development of resilient structure for forest biomass and bioenergy SC.

4.2.5. Strategic enablers

Strategic enablers play important role in implementation of the sustainable practices, policies, procedures, etc. by affecting the cyclical structure of the economy as well as regulating the size and level of SCNs based on the potentials and needs (Caldera, Desha, & Dawes, 2019; Dashtpeyma & Ghodsi, 2021). It indicates that these enablers can change the direction of decision-making quiddity. Also, one of the main functions of strategies is creating sustainable harmony among the goals, plans and activities within forest biomass and bioenergy SCN (Zahraee, Golroudbary, Shiwakoti, & Stasinopoulos, 2021). In recent years, constant and innovative development is achievable by enabling the strategies that of course industries follow to ensure success in local and global markets (Siagian et al., 2021). Therefore, to deal with the uncertainties in short-term, medium-term, and long-term organizational goals and plans, identification and promoting the strategic enablers should be considered as an important issue. Based on the results, the path coefficient between the "strategic enablers" and "resilience enablers" is significant (0.829). It proves that improving these enablers play an important role in advancing the resilience enablers leading to development of resilient structure for forest biomass and bioenergy SC.

4.3. Resilience KPIs of the forest biomass and bioenergy SC

Resilience KPIs of the forest biomass and bioenergy SC are the most important measurement tools for measuring the performance quality at all levels. In fact, these KPIs are the vital and prospective requirements that should be explored to make the optimal effect on the inputs and outputs of a business in direct and indirect way (Chan & Chan, 2004; Werner, Yamada, Domingos, Leite, & Pereira, 2021). Therefore, constant investigation on the mentioned KPIs can provide a situation for managers to improve their performance level based on the changes required. Based on the results, the path coefficient between the "resilience KPIs" and "forest biomass and bioenergy supply chain resilience" is significant (0.913). It proves that by promoting these KPIs, a resilient structure can be developed for forest biomass and bioenergy SC.

4.3.1. Financial performance

Financial performance plays undeniable role in regulating the investments and assets with the costs and revenues within all sizes of the forest biomass and bioenergy SCNs (Dashtpeyma & Ghodsi, 2021; Lo et al., 2021). Constant improvement of the performance quality for financial aspect provides a situation for managers to make effective decisions just in time (Breuer & de Vargas, 2021). Hence, development and optimization of a detailed and on-going financial performance level will lead to a more resilient forest biomass and bioenergy SC. Based on the results, the path coefficient between the "financial performance" and "resilience KPIs" is desirable (0.611). It proves that by promoting this KPI, a resilient structure can be developed for forest biomass and bioenergy SC.

4.3.2. Forest management performance

Forest management is one of the main functions of the forest-based industries by which the quantity and quality of financial and non-financial inputs and outputs as well as the future and size of the relevant industries can be assessed, improved, and managed (Cambero & Sowlati, 2014). It has an important relationship with the deforestation, afforestation, and reforestation processes illustrating its impact on the decision-making process in the field of the forest biomass and bioenergy SC (Dashtpeyma & Ghodsi, 2021; Pinto, Sousa, & Valente, 2022; Sasaki, 2021). Therefore, the more optimal, stable and dynamic forest management performance, the more resilient forest biomass and bioenergy SC will be. Based on the results, the path coefficient between the "forest management performance" and "resilience KPIs" is desirable (0.787). It proves that by promoting this KPI, a resilient structure can be developed for forest biomass and bioenergy SC.

4.3.3. Marketing performance

Marketing is one of the most important steps in starting and developing a successful forest biomass and bioenergy SC (Dashtpeyma & Ghodsi, 2021). How to manage potentials, needs, and changes of the marketplaces determines the accessible shares from local and global markets in favor of the forest biomass and bioenergy industries (Garren, Bolding, Barrett, Aust, & Coates, 2022; Jåstad, Bolkesjø, Trømborg, & Rørstad, 2021). Indeed, by implementing an efficient marketing control, the performance quality can be improved based on the standards (Hadrian, Milichovský, & Mráček, 2021). Accordingly, by updating and improving the compatibility of marketing performance, a more resilient forest biomass and bioenergy SC can be achieved. Based on the results, the path coefficient between the "marketing performance" and "resilience KPIs" is desirable (0.736). It proves that by improving this KPI, a resilient structure can be developed for forest biomass and bioenergy SC.

4.3.4. Customer orientation performance

Creating a balance between customer expectations, and capabilities of the forest biomass and bioenergy SCs is one of the most important factors in impact on sustainability level against uncertainty and changeability of the marketplaces (Dashtpeyma & Ghodsi, 2021). In fact, targeting, planning and activities should be implemented by considering the customers feedbacks to efficiently deal with difficulties in the turbulent business environment (NWANKWO, 1993; Tauro et al., 2021). Therefore, by prioritizing the logical needs and demands of real customers that leads to an optimal customer orientation performance, a more resilient forest biomass and bioenergy SC can be achieved. Based on the results, the path coefficient between the "customer orientation performance" and "resilience KPIs" is desirable (0.672). It proves that by promoting this KPI, a resilient structure can be developed for forest biomass and bioenergy SC.

4.3.5. Human resource performance

Optimal quality and quantity of the human resources is one of the critical issues in constant success of the forest-based SCs depending on the levels of knowledge and experience of staffs as managers and non-managers (Choksi, 2022; Dashtpeyma & Ghodsi, 2021). Increasing the performance level during the management process of human resource would be invaluable in helping the industries to achieve high commitment level among the members as well as obtaining the competitive advantages (Collins, 2021). Hence, by creating a scientific and practical framework for evaluating and improving the level of human resources that leads to an optimal human resource performance, a resilient structure can be developed for forest biomass and bioenergy SC. Based on the results, the path coefficient between the "human resource performance" and "resilience KPIs" is desirable (0.787). It proves that by promoting this KPI, a resilient structure can be developed for forest biomass and bioenergy SC.

4.3.6. Hardware System Performance

Hardware system includes all physical structure used within the forest biomass and bioenergy SCN as well as the order between them, in such a way that without their sufficient efficiency, theories and plans cannot be carried out (Dashtpeyma & Ghodsi, 2021; Galik et al., 2021). In fact, high performance level for managing the hardware system lead to better control the costs, optimal time and capacity to supply and demand of goods and services, and reduce the inherent risks (J. Wang, Yang, & Wang, 2020; Zhang, Wang, & Strager, 2022). Hence, by modernizing the hardware system structure leading to the optimal performance level, a resilient structure can be developed for forest biomass and bioenergy SC. Based on the results, the path coefficient between the "hardware system performance" and "resilience KPIs" is desirable (0.649). It proves that by promoting this KPI, a resilient structure can be developed for forest biomass and bioenergy SC.

4.3.7. Software System Performance

In recent years, the optimal use of cyberspace has playing an important role in advancing the goals and plans within SCNs (Dashtpeyma & Ghodsi, 2021). Therefore, dealing with challenges such as cyber-attacks, disinformation, and misinformation as well as utilizing the capacities to expand the influence level requires a comprehensive platform. Improving the level of performance to optimize the structure of the software system can have a positive effect on facilitating the processes and flows (Athanasopoulos, Theodoridis, Darisaplis, & Stamelos, 2019). Accordingly, by developing and applying the integrated and up-to-date software system not only the management performance will be improved, but also a resilient structure can be developed for forest biomass and bioenergy SC. Based on the results, the path coefficient between the "software system performance" and "resilience KPIs" is desirable (0.757). It proves that by promoting this KPI, a resilient structure can be developed for forest biomass and bioenergy SC.

4.4. Resilience practices of the forest biomass and bioenergy SC

Resilience practices are fundamental factors in helping restore performance upon disruption during the processes and flows within the SCN (Birkie, Trucco, & Campos, 2017; Carvalho, Naghshineh, Govindan, & Cruz-Machado, 2022). They are considered as the principles of a roadmap to strengthen the resilience capability of system structure for the forest biomass and bioenergy SC. In fact, they play important roles in optimizing the resilience level of the goals, plans, and activities in uncertain situations of local and global business environments (Dashtpeyma & Ghodsi, 2019, 2021; Sangari & Dashtpeyma, 2019). Based on the results, the path coefficient between the “resilience practices” and “forest biomass and bioenergy supply chain resilience” is significant (0.946). It proves that by improving these practices, a resilient structure can be developed for forest biomass and bioenergy SC.

4.4.1. Adaptability

Forest biomass and bioenergy SCNs often face challenges such as changeability and uncertainty on the needs and the ability to meet them. The adaptability can be effective in constructive interacting with positive changes while increasing resilience for sustainable development during negative changes (Dashtpeyma & Ghodsi, 2021; Sangari & Dashtpeyma, 2019). Based on the results, the path coefficient between the “adaptability” and “resilience practices” is significant (0.696). It proves that by improving this practice, a resilient structure can be developed for forest biomass and bioenergy SC.

4.4.2. Anticipation

Anticipating the future events and how to deal with them can affect the level of stability in uncertain forest biomass and bioenergy SCNs. In fact, anticipation is one of the resilience components for SCs to mitigate the risks and disruptions as well as increasing the capability of system to deal with the expected and unexpected events (Dashtpeyma & Ghodsi, 2021; Sangari & Dashtpeyma, 2019). Based on the results, the path coefficient between the “anticipation” and “resilience practices” is significant (0.675). It proves that by improving this practice, a resilient structure can be developed for forest biomass and bioenergy SC.

4.4.3. Collaboration

Constant collaboration, taking into account the interests of the parties, can expand the size of forest-based SCNs and optimize the capacity to provide products and services in different situations. Indeed, collaboration within the SCN and out-of-network can help managers increase resilience level by strengthening the performance quality at the tactical, operational, or strategic levels (Dashtpeyma & Ghodsi, 2021; Sangari & Dashtpeyma, 2019). Based on the results, the path coefficient between the “collaboration” and “resilience practices” is significant (0.703). It proves that by improving this practice, a resilient structure can be developed for forest biomass and bioenergy SC.

4.4.4. Commitment

Committed human resource is a necessary and vital factor to perform the activities accurately and correctly at any level. Therefore, high level of commitment within the SCN provides a situation for managers to interact with skillful and reliable staffs leading to resilient management in financial and non-financial crises (Dashtpeyma & Ghodsi, 2021; Sangari & Dashtpeyma, 2019). Based on the results, the path coefficient between the “commitment” and “resilience practices” is significant (0.694). It proves that by improving this practice, a resilient structure can be developed for forest biomass and bioenergy SC.

4.4.5. Flexibility

The forest biomass and bioenergy SCN must have a flexible structure to be able to maintain its overall goals and plans and to act efficiently in the face of new changes and needs. Flexibility is one of the main factors of resilience capability in the field of SCM that play significant role in the developing and optimizing the system structure during uncertain situations (Dashtpeyma & Ghodsi, 2021; Sangari & Dashtpeyma, 2019). Based on the results, the path coefficient between the “flexibility” and “resilience practices” is significant (0.679). It proves that by improving this practice, a resilient structure can be developed for forest biomass and bioenergy SC.

4.4.6. Information technology

Due to the increasing importance of information in directing the attitudes of producers and consumers in the marketplaces, the use of new and optimal information technologies can promote the structural resilience of forest biomass and bioenergy SCN. These type of technologies not only increase the quality and quantity of relationships and interactions in the SCN, but also mitigate the impact of risks on efficiency level (Dashtpeyma & Ghodsi, 2021; Sangari &

Dashtpeyma, 2019). Based on the results, the path coefficient between the "information technology" and "resilience practices" is significant (0.704). It proves that by improving this practice, a resilient structure can be developed for forest biomass and bioenergy SC.

4.4.7. Innovation

Constant innovation is one of the effective factors to deal with changes in the competitive forest-based market and consumer expectations. In fact, it improves the resilience level within SCN by contributing to developing a preventive and prospective structure during establishment, survival, and growth of the industries (Dashtpeyma & Ghodsi, 2021; Sangari & Dashtpeyma, 2019). Based on the results, the path coefficient between the "innovation" and "resilience practices" is significant (0.718). It proves that by improving this practice, a resilient structure can be developed for forest biomass and bioenergy SC.

4.4.8. Integration

One of the most important steps in sustainable development in forest biomass and bioenergy SCs is to integrate goals, plans and activities with the present and future potentials and needs (Dashtpeyma & Ghodsi, 2021). Also, it is considered as the key factor of resilience capability within SCNs by which the market share and competitive advantage can be increased (Sangari & Dashtpeyma, 2019). Based on the results, the path coefficient between the "integration" and "resilience practices" is significant (0.718). It proves that by improving this practice, a resilient structure can be developed for forest biomass and bioenergy SC.

4.4.9. Leadership

Leadership is an effective factor in positively orienting the goals, plans and activities in today's competitive forest-based industries (Dashtpeyma & Ghodsi, 2021). In fact, by optimal leadership ability, the top authorities of the SCNs can establish a constructive interaction between idealism and realism, which in turn will increase managerial skills (Sangari & Dashtpeyma, 2019). Based on the results, the path coefficient between the "leadership" and "resilience practices" is significant (0.642). It proves that by improving this practice, a resilient structure can be developed for forest biomass and bioenergy SC.

4.4.10. Redundancy

A redundant system structure helps administrators of the forest biomass and bioenergy SC use parallel tools and procedures in critical situations as an alternative in an accurate and quick way (Dashtpeyma & Ghodsi, 2021). In fact, redundancy significantly improves the capacity of SCN to reduce the risk levels as well as increasing the resource access rate throughout the flows and processes (Sangari & Dashtpeyma, 2019). Based on the results, the path coefficient between the "redundancy" and "resilience practices" is significant (0.741). It proves that by improving this practice, a resilient structure can be developed for forest biomass and bioenergy SC.

4.4.11. Responsiveness

Effectively responding to the demands or meeting the needs of members of forest biomass and bioenergy SCN and customers of goods and services almost always determine how such successful businesses can be in the globalization process (Dashtpeyma & Ghodsi, 2021). Therefore, the quantity and quality of response in critical situations where supply and demand are fluctuating is directly related to the resilience of the entire SCN (Sangari & Dashtpeyma, 2019). Based on the results, the path coefficient between the "responsiveness" and "resilience practices" is significant (0.710). It proves that by improving this practice, a resilient structure can be developed for forest biomass and bioenergy SC.

4.4.12. Risk management

Optimal risk management is a key factor for the forest biomass and bioenergy SCN to be more structural resilient in the critical situations (Dashtpeyma & Ghodsi, 2021). It is an efficient ability to manage and reduce the risk rate within the SC flows and processes as well as improving the recovery power during and after disruptions (Sangari & Dashtpeyma, 2019). Based on the results, the path coefficient between the "risk management" and "resilience practices" is significant (0.746). It proves that by improving this practice, a resilient structure can be developed for forest biomass and bioenergy SC.

4.4.13. Robustness

To deal with the challenges in the competitive marketplaces in forest-based industries, developing a robust structure is of great importance (Dashtpeyma & Ghodsi, 2021). Indeed, high level of robustness help managers continue to do the

SC functions in reliable level given internal and external shocks and crises (Sangari & Dashtpeyma, 2019). Based on the results, the path coefficient between the “robustness” and “resilience practices” is significant (0.664). It proves that by improving this practice, a resilient structure can be developed for forest biomass and bioenergy SC.

4.4.14. Vulnerability

The degree of vulnerability of enterprises to environmental, economic, social, technical and strategic events determines the degree of their sustainability in the competitive and unfair marketplaces in forest-based industries (Dashtpeyma & Ghodsi, 2021). In fact, vulnerability plays significant role in improving the resilience level by reducing the impact of inherent and non-intrinsic hazards and crises for the SCN (Sangari & Dashtpeyma, 2019). Based on the results, the path coefficient between the “vulnerability” and “resilience practices” is significant (0.645). It proves that by improving this practice, a resilient structure can be developed for forest biomass and bioenergy SC.

4.5. Potential stakeholders

Potential stakeholders are the main supporters, determinants, and decision makers on the goals, plans and activities in the forest biomass and bioenergy SCN. Therefore, the type and intensity of their relationships with the resilience capability will have a significant impact on SC performance. Based on the results, the path coefficient between the “potential stakeholders” and "forest biomass and bioenergy supply chain resilience" is significant (0.888). It proves that by identifying, evaluating, categorizing these potential stakeholders, and improving relationships and interactions with them, a resilient structure can be developed for forest biomass and bioenergy SC. Also, the path coefficients among the “communities”, "customers", "distributers", “employees”, “governments”, “investors”, "suppliers" with the “potential stakeholders” are significant (0.768, 0.636, 0.536, 0.638, 0.694, 0.651, and 0.674, respectively). It proves that by improving the quality and quantity of relationships and interactions with each of potential stakeholders, a resilient structure can be developed for forest biomass and bioenergy SC.

4.6. Research gap to address in this research

Although the discussion on creating and optimizing the resilience capability is very pervasive in many areas, it has not yet been practically addressed in the field of forest biomass and bioenergy SC. Reviewing the relevant literature, it can be noticed that it is one of the significant research gaps in the field. To bridge the gap, conducting experimental research and presenting theoretical and managerial implications seem necessary.

In this research paper, an inclusive conceptual decision-making model is proposed to design, deploy, develop, and optimize a resilient forest biomass and bioenergy SC for the first time. The comprehensive and specific definitions are provided for all the components of the proposed model, especially forest biomass and bioenergy SCR. The nature of each component of and interactions among them give novel and effective insights to such business owners about the importance of resilience capability to improve performance in different situations. Therefore, the significant findings of this research can be used as a valuable resource by researchers and managers to bridge research and managerial gaps in this way.

Appendix

The questions of the questionnaire are:

- Q1. Uncertainty level of environmental barriers significantly impacts on the resilience barriers of forest biomass and bioenergy SC.
- Q2. Quantity or severity of environmental barriers significantly impacts on the resilience barriers of forest biomass and bioenergy SC.
- Q3. Quality or intensity of environmental barriers significantly impacts on the resilience barriers of forest biomass and bioenergy SC.
- Q4. Uncertainty level of economic barriers significantly impacts on the resilience barriers of forest biomass and bioenergy SC.
- Q5. Quantity or severity of economic barriers significantly impacts on the resilience barriers of forest biomass and bioenergy SC.
- Q6. Quality or intensity of economic barriers significantly impacts on the resilience barriers of forest biomass and bioenergy SC.
- Q7. Uncertainty level of social barriers significantly impacts on the resilience barriers of forest biomass and bioenergy SC.

- Q8. Quantity or severity of social barriers significantly impacts on the resilience barriers of forest biomass and bioenergy SC.
- Q9. Quality or intensity of social barriers significantly impacts on the resilience barriers of forest biomass and bioenergy SC.
- Q10. Uncertainty level of technical barriers significantly impacts on the resilience barriers of forest biomass and bioenergy SC.
- Q11. Quantity or severity of technical barriers significantly impacts on the resilience barriers of forest biomass and bioenergy SC.
- Q12. Quality or intensity of technical barriers significantly impacts on the resilience barriers of forest biomass and bioenergy SC.
- Q13. Uncertainty level of strategic barriers significantly impacts on the resilience barriers of forest biomass and bioenergy SC.
- Q14. Quantity or severity of strategic barriers significantly impacts on the resilience barriers of forest biomass and bioenergy SC.
- Q15. Quality or intensity of strategic barriers significantly impacts on the resilience barriers of forest biomass and bioenergy SC.
- Q16. Uncertainty level of environmental enablers significantly impacts on the resilience enablers of forest biomass and bioenergy SC.
- Q17. Quantity or severity of environmental enablers significantly impacts on the resilience enablers of forest biomass and bioenergy SC.
- Q18. Quality or intensity of environmental enablers significantly impacts on the resilience enablers of forest biomass and bioenergy SC.
- Q19. Uncertainty level of economic enablers significantly impacts on the resilience enablers of forest biomass and bioenergy SC.
- Q20. Quantity or severity of economic enablers significantly impacts on the resilience enablers of forest biomass and bioenergy SC.
- Q21. Quality or intensity of economic enablers significantly impacts on the resilience enablers of forest biomass and bioenergy SC.
- Q22. Uncertainty level of social enablers significantly impacts on the resilience enablers of forest biomass and bioenergy SC.
- Q23. Quantity or severity of social enablers significantly impacts on the resilience enablers of forest biomass and bioenergy SC.
- Q24. Quality or intensity of social enablers significantly impacts on the resilience enablers of forest biomass and bioenergy SC.
- Q25. Uncertainty level of technical enablers significantly impacts on the resilience enablers of forest biomass and bioenergy SC.
- Q26. Quantity or severity of technical enablers significantly impacts on the resilience enablers of forest biomass and bioenergy SC.
- Q27. Quality or intensity of technical enablers significantly impacts on the resilience enablers of forest biomass and bioenergy SC.
- Q28. Uncertainty level of strategic enablers significantly impacts on the resilience enablers of forest biomass and bioenergy SC.
- Q29. Quantity or severity of strategic enablers significantly impacts on the resilience enablers of forest biomass and bioenergy SC.
- Q30. Quality or intensity of strategic enablers significantly impacts on the resilience enablers of forest biomass and bioenergy SC.
- Q31. Uncertainty level of financial performance significantly impacts on the resilience KPIs of forest biomass and bioenergy SC.
- Q32. Quantity or severity of financial performance significantly impacts on the resilience KPIs of forest biomass and bioenergy SC.
- Q33. Quality or intensity of financial performance significantly impacts on the resilience KPIs of forest biomass and bioenergy SC.
- Q34. Uncertainty level of forest management performance significantly impacts on the resilience KPIs of forest biomass and bioenergy SC.
- Q35. Quantity or severity of forest management performance significantly impacts on the resilience KPIs of forest biomass and bioenergy SC.
- Q36. Quality or intensity of forest management performance significantly impacts on the resilience KPIs of forest biomass and bioenergy SC.

- Q37. Uncertainty level of marketing performance significantly impacts on the resilience KPIs of forest biomass and bioenergy SC.
- Q38. Quantity or severity of marketing performance significantly impacts on the resilience KPIs of forest biomass and bioenergy SC.
- Q39. Quality or intensity of marketing performance significantly impacts on the resilience KPIs of forest biomass and bioenergy SC.
- Q40. Uncertainty level of customer orientation performance significantly impacts on the resilience KPIs of forest biomass and bioenergy SC.
- Q41. Quantity or severity of customer orientation performance significantly impacts on the resilience KPIs of forest biomass and bioenergy SC.
- Q42. Quality or intensity of customer orientation performance significantly impacts on the resilience KPIs of forest biomass and bioenergy SC.
- Q43. Uncertainty level of human resource performance significantly impacts on the resilience KPIs of forest biomass and bioenergy SC.
- Q44. Quantity or severity of human resource performance significantly impacts on the resilience KPIs of forest biomass and bioenergy SC.
- Q45. Quality or intensity of human resource performance significantly impacts on the resilience KPIs of forest biomass and bioenergy SC.
- Q46. Uncertainty level of hardware system performance significantly impacts on the resilience KPIs of forest biomass and bioenergy SC.
- Q47. Quantity or severity of hardware system management performance significantly impacts on the resilience KPIs of forest biomass and bioenergy SC.
- Q48. Quality or intensity of hardware system performance significantly impacts on the resilience KPIs of forest biomass and bioenergy SC.
- Q49. Uncertainty level of software system performance significantly impacts on the resilience KPIs of forest biomass and bioenergy SC.
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- Q52. Uncertainty level of adaptability significantly impacts on the resilience practices of forest biomass and bioenergy SC.
- Q53. Quantity or severity of adaptability significantly impacts on the resilience practices of forest biomass and bioenergy SC.
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- Q58. Uncertainty level of collaboration significantly impacts on the resilience practices of forest biomass and bioenergy SC.
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- Q61. Uncertainty level of commitment significantly impacts on the resilience practices of forest biomass and bioenergy SC.
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- Q64. Uncertainty level of flexibility significantly impacts on the resilience practices of forest biomass and bioenergy SC.
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- Q66. Quality or intensity of flexibility significantly impacts on the resilience practices of forest biomass and bioenergy SC.
- Q67. Uncertainty level of information technology significantly impacts on the resilience practices of forest biomass and bioenergy SC.
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- Q73. Uncertainty level of integration significantly impacts on the resilience practices of forest biomass and bioenergy SC.
- Q74. Quantity or severity of integration significantly impacts on the resilience practices of forest biomass and bioenergy SC.
- Q75. Quality or intensity of integration significantly impacts on the resilience practices of forest biomass and bioenergy SC.
- Q76. Uncertainty level of leadership significantly impacts on the resilience practices of forest biomass and bioenergy SC.
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- Q80. Quantity or severity of redundancy significantly impacts on the resilience practices of forest biomass and bioenergy SC.
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- Q82. Uncertainty level of responsiveness significantly impacts on the resilience practices of forest biomass and bioenergy SC.
- Q83. Quantity or severity of responsiveness significantly impacts on the resilience practices of forest biomass and bioenergy SC.
- Q84. Quality or intensity of responsiveness significantly impacts on the resilience practices of forest biomass and bioenergy SC.
- Q85. Uncertainty level of risk management significantly impacts on the resilience practices of forest biomass and bioenergy SC.
- Q86. Quantity or severity of risk management significantly impacts on the resilience practices of forest biomass and bioenergy SC.
- Q87. Quality or intensity of risk management on the resilience practices of forest biomass and bioenergy SC.
- Q88. Uncertainty level of robustness significantly impacts on the resilience practices of forest biomass and bioenergy SC.
- Q89. Quantity or severity of robustness significantly impacts on the resilience practices of forest biomass and bioenergy SC.
- Q90. Quality or intensity of robustness significantly impacts on the resilience practices of forest biomass and bioenergy SC.
- Q91. Uncertainty level of vulnerability significantly impacts on the resilience practices of forest biomass and bioenergy SC.
- Q92. Quantity or severity of vulnerability significantly impacts on the resilience practices of forest biomass and bioenergy SC.
- Q93. Quality or intensity of vulnerability significantly impacts on the resilience practices of forest biomass and bioenergy SC.
- Q94. Uncertainty level of communities significantly impacts on the potentiality of stakeholders in forest biomass and bioenergy SC.

- Q95. Quantity or severity of communities significantly impacts on the potentiality of stakeholders in forest biomass and bioenergy SC.
- Q96. Quality or intensity of communities significantly impacts on the potentiality of stakeholders in forest biomass and bioenergy SC.
- Q97. Uncertainty level of customers significantly impacts on the potentiality of stakeholders in forest biomass and bioenergy SC.
- Q98. Quantity or severity of customers significantly impacts on the potentiality of stakeholders in forest biomass and bioenergy SC.
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- Q104. Quantity or severity of employees significantly impacts on the potentiality of stakeholders in forest biomass and bioenergy SC.
- Q105. Quality or intensity of employees significantly impacts on the potentiality of stakeholders in forest biomass and bioenergy SC.
- Q106. Uncertainty level of governments significantly impacts on the potentiality of stakeholders in forest biomass and bioenergy SC.
- Q107. Quantity or severity of governments significantly impacts on the potentiality of stakeholders in forest biomass and bioenergy SC.
- Q108. Quality or intensity of governments significantly impacts on the potentiality of stakeholders in forest biomass and bioenergy SC.
- Q109. Uncertainty level of investors significantly impacts on the potentiality of stakeholders in forest biomass and bioenergy SC.
- Q110. Quantity or severity of investors significantly impacts on the potentiality of stakeholders in forest biomass and bioenergy SC.
- Q111. Quality or intensity of investors significantly impacts on the potentiality of stakeholders in forest biomass and bioenergy SC.
- Q112. Uncertainty level of suppliers significantly impacts on the potentiality of stakeholders in forest biomass and bioenergy SC.
- Q113. Quantity or severity of suppliers significantly impacts on the potentiality of stakeholders in forest biomass and bioenergy SC.
- Q114. Quality or intensity of suppliers significantly impacts on the potentiality of stakeholders in forest biomass and bioenergy SC

5. Conclusion

Insofar as this research aimed to investigate all essential components of the resilience capability for forest biomass and bioenergy SC in form of a decision-making model, the following findings are obtained. A significant research gap on the practical application and optimization of resilience concept in the scope of forest biomass and bioenergy SC is recognized by reviewing the literature, which is the lack of a resilient decision-making structure in the field. To bridge the research, gap a standard procedure was considered. The essential resilience components within forest biomass and bioenergy SCN are determined including barriers, enablers, KPIs, practices and potential stakeholders. Then, a conceptual decision-making model was designed to investigate the value of interactions among them as hypotheses. To this end, the SmartPLS3 was applied for validating the proposed model. The results indicated that all the components and hypothesis are great of importance. In this context, the hypothesis of an effective relationship between the determined resilience components and the forest biomass and bioenergy SCR is proved. This indicates the extent to which each resilience component is involved in the design, deployment, development, and optimization of such a structure for relevant SCN. One of the most important parts of this research is incorporated within the discussion section, in which specific definitions and managerial implications are provided for all resilience components of forest biomass and bioenergy SC. Of course, the comprehensive definitions for all the resilience components are also provided in this research, indicating that the overall findings are reliable. Also, the decision-making model in structural, measurement and general dimensions are highly acceptable. Hence, a set of reliable and detailed results are achieved in this research work.

Research limitations

As research limitations, the following can be mentioned:

- The statistical community and data collection process were limited to a specific area with fewer options.
- The data collected for the research is related to a limited and specific time period.
- Only one modeling procedure was used to evaluate the research queries.

Research suggestions

As research suggestions, the following can be mentioned:

- For future research works, it is better to select a larger and more diverse statistical community in different countries with different forest biomass and bioenergy SCN sizes and levels.
- For future research work, it is better to collect data in different time periods so that the effect of time factor on the results can be investigated.
- For future research work, it is better to apply mathematical modeling, simulation and also combined approaches to examine the different dimensions of quantity and quality of the subject.

Compliance with ethical standards

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This research has been done by the author independently.

Author contributions

All research steps are performed by the author of the article.

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Data availability

Although the data used in this study are obtainable, the dataset used will not be available, since data-sharing is prohibited by the contract with the author.

Disclosure of conflict of interest

The author has no relevant financial or non-financial interests to disclose.

Statement of ethical approval

Ethics approval was not needed for the present study.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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