

coupled with discussions with the experts in the field. Once the concept was sustainability was comprehended, the next stage of the research was to identify a set of critical risks that could affect supply chain sustainability and prioritization of the identified risks comprised the final stage of the research. The prioritization of the identified risks was conducted through the use of the multi criteria decision-making technique of AHP and a set of subject matter experts were provided with the AHP questionnaire and the risks prioritized based on their responses. The subject matter experts consisted of eminent industry professional with a considerable experience in the domain of supply chain sustainability. Table 2 exhibited below illustrates the research stages and the methodologies used in each stage.

TABLE 2. RESEARCH STAGES AND METHODOLOGIES

Research stages	Methodologies
Understanding the concept of supply chain sustainability	Review of open literature on the subject, discussion with subject matter experts and industry professionals
Identification of a set of critical risks associated with supply chain sustainability	Discussion with subject matter experts and literature review
Prioritization of the identified risks using AHP	Survey of subject matter experts

IV. IDENTIFYING THE RISKS ASSOCIATED WITH SUPPLY CHAIN SUSTAINABILITY

The primary objective of the research process was to identify and prioritize a set of critical risks associated with supply chain sustainability. Sustainability, which includes considering the social and environmental factors in addition to the economic factors, requires a broader SCM strategy on the part of the organizations. A sustainable supply chain requires a greater symbiosis among partnering companies in order to make the supply chain operational and to reach sustainable performance [20]. A sustainable operations and supply chain strategy concerns both the operational drivers of profitability and their relationship to people and the planet [24] and therefore, need to consider environmental and social criteria in the performance objectives the management of the whole supply chain, in addition to the organization itself [20, 21]. As a result, a sustainable supply chain can be exposed to a plethora of uncertainties and risk factors that needs to be addressed by the decision-makers along with chalking out mitigation strategies for the same. The remainder of this section will be devoted towards a discussion of the identified risks associated with supply chain sustainability and their subsequent prioritization to assess relative criticality.

The first stage of the overall risk evaluation process consisted of enlisting a set on important risks associated with supply chain sustainability. After careful review of the literature on supply chain sustainability and discussion with experts in the field, the authors arrived at a set of critical risks which are enlisted in table 2, along with their operational definition. A brief explanation of the risks follows table 2.

TABLE 2. RISKS ASSOCIATED WITH SUPPLY CHAIN SUSTAINABILITY

Risks	Operational Definition
Supplier / sub supplier risks	The selected suppliers and sub suppliers does not follows the sustainability guidelines or does not have required ISO certifications or and have failed to comply with the sustainability requirements.
Legal risks	The legal risks associated with the violation of sustainability guidelines and norms
Transportation & Logistics risks	The risks associated with the failure of the mode of transportation and logistics (including reverse logistics) involved in the supply chain process being able to comply with the sustainability regulations
Human resource risks	Risks associated with the violation of labor laws and human rights, including disregard for local communities, working condition, fair wages, discrimination, etc.
Risks associated with end of product life cycle, including waste management	Risks associated with the failure / compromise in the waste reduction process across supply chain, as well as a negative environmental impact of reclamation, reuse, and recycling - thereby leading to a violation in the sustainability norms.

Supplier / Sub-supplier risks: One of the key requirements for achieving a sustainable supply chain includes all of the members in the chain from suppliers to top managers having affinity with sustainability [22]. Even though environmental considerations in supplier selection decisions have existed, it is still lacking the inclusion of other factors of sustainability [21]. Supplier selection is considered as one of the most complicated parts of supply chain management chain and it has the probability to harbor a lot of risks within it. Since the downstream supply can stretch very far, it is very difficult to walk down the whole line. So it is extremely essential that supplier selected complies with sustainability guidelines. Suppliers having ISO 1400/14001 certification is can be a preliminary requirement. Supplier selection is a strategic decision and the supplier's environmental and labor law compliance history must be well researched. In case of single supplier strategy this becomes more important because any disruption from supplier side will adversely affect the focal firm's business. The risks associated with the failure to select suppliers who comply with the guidelines and norms of sustainability is termed as supplier risks in the context of this research.

Legal Risks: According to [23], irresponsible supplier behavior may cause adverse publicity, reputational damage, and costly legal obligations. All these might lead to a substantial financial damage to the company. The risks that an organization suffering as a result of a legal litigation arising out of a violation in its sustainable supply chain (and business) practices is termed as legal risks.

Transportation and Logistics Risks: Transportation in supply chain has also considerable effect on environment as one of the main sources of NO_x and SO_x gas emission in the environment [27]. Regulatory policies and laws have imposed hefty fines and reduction of carbon footprints is also incentivized. The risks associated with the failure to adhere to the environmentally sustainable logistics process in the supply chain can be stated as transportation / logistics risks. The transportation and logistics risk also implicitly includes any hazards created due to packaging design, material weight and volume risks which can adversely affect transportation.

Human resource risks: Companies have a responsibility to respect human rights. The baseline responsibility is not to infringe on the rights of others. Labor conditions in offices, in factories, on farms and at natural resource extraction sites such as mines, particularly in the developing world, often fall significantly below international standards and national regulatory requirements and can lead to serious human rights abuses [28]. Companies should also mold their culture and operations according to the local culture and involve with local communities for empowering their living conditions, which as a sustainable practice. The risks associated with a failure to achieve the above can be termed as human resource risks in the context of the current research.

Risks associated with product end of life and waste management: Material and handling in manufacturing poses considerable risk to sustainability. Toxic waste, water pollution and effluent Carbon/ Sulphur dioxides often cause long term environmental impacts. Emphasis on reduction of waste during manufacturing [27] is a key factor in sustainable supply chain. Recent incident of manhandling of toxic mercury waste in Kodaikanal HUL factory has received much attention and is an example that shows that such risk remain pertinent.

Furthermore, enterprises nowadays put more emphasis on reverse logistics due to social responsibility and customer expectation [25]. However, failure to conduct the reverse logistics process at the end of product life in a sustainable manner, thereby preserving the TBL of the organization can lead to huge cost and reputational implication for the organization in question. The risks associated with a negative environmental impact of reclamation, reuse, and recycling - thereby leading to a violation in the sustainability norms - is considered as end of product lifecycle risks in the context of the present research.

IV. PRIORITIZING THE RISKS ASSOCIATED WITH SUPPLY CHAIN SUSTAINABILITY

As stated earlier, the identified risks associated with the supply chain sustainability of an organization was subsequently prioritized to assess their relative criticality. This was done using the MCDM technique of AHP. Once the risks were identified, the next stage of the research process consisted of laying down the identified risks in the form of AHP architecture as shown in figure 3.

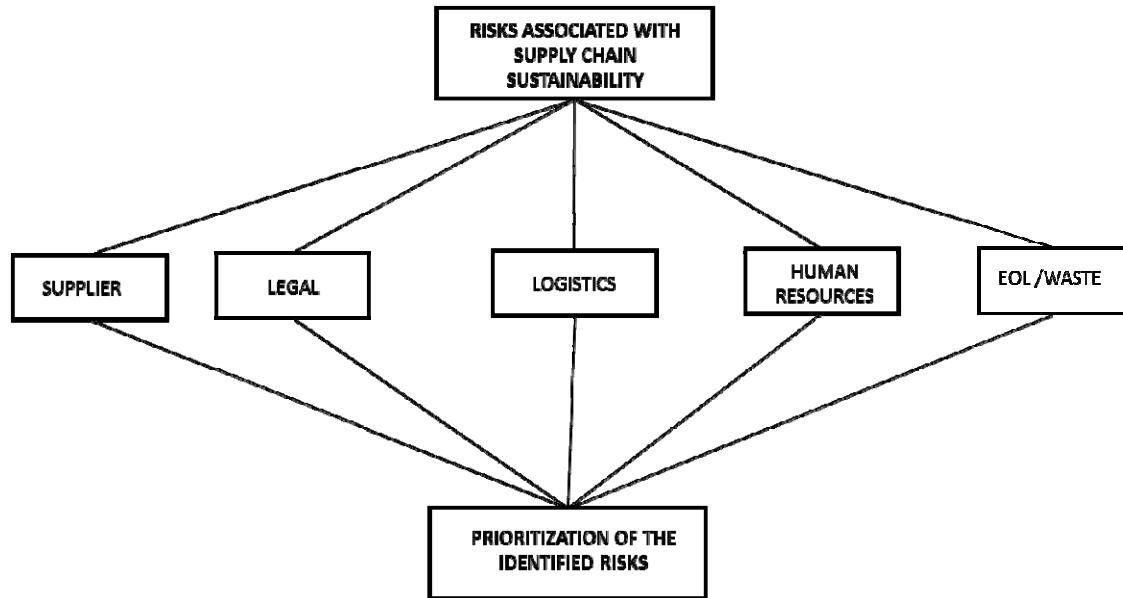


Fig. 3. AHP structure of the research model

As seen from figure 3, the primary objective of the research process was to arrive at prioritized rankings of the set of the risks associated with supply chain sustainability. This is the first level of hierarchy (or what Saaty calls, the focus). The second level of the hierarchy was the set of the operational constraints that were to be evaluated and subsequently ranked according to their order of importance. It should be mentioned at this point that in most cases, the final level of hierarchy in any AHP structure consists of the set of alternatives that have to be compared as a part of the overall selection process. However, in the context of this research, where the main purpose of the research is to prioritize a set of operational constraints, enlisting a set of final alternatives was thought to be redundant and therefore was not done. The last level of hierarchy in figure 3, which is nothing but the overall ranking, is included to depict the overall research process in the form of an AHP structure.

As a part of the process, an AHP questionnaire was constructed and distributed to a set of subject matter experts. The subject matter experts identified as survey respondents were eminent industry and academic professionals having a substantial experience in the area of supply chain sustainability. The AHP questionnaire distributed to the respondents included the six major risks associated with supply chain sustainability and the evaluators were requested to perform a pair wise comparison among the attributes. As there were five risks that were selected, the total number of pair wise comparisons that each of the evaluators had to make were $(n*(n-1) / 2) = 10$. The feedback received from the evaluators was then combined and normalized in order to obtain the global priority weights for each of the attributes. A pair wise comparison among the five risks selected along with their mean normalized weights as provided by one of the experts is shown in table 3.

TABLE 3. PAIR WISE COMPARISON AMONG THE RISKS AND THEIR NORMALIZED WEIGHTS FROM ONE OF THE SURVEYS

RISKS	Supplier	Legal	Logistics	Human Resources	Product EOL / Waste	Mean Normalized Values
Supplier	1	9	7	5	5	0.5062
Legal	1/9	1	3	1/7	1/7	0.0513
Logistics	1/7	1/3	1	1/9	1/7	0.0339
Human Resources	1/5	7	9	1	3	0.2434
Product EOL / Waste	1/5	7	7	1/3	1	0.1652

It should be mentioned here that table 3 depicts the pair wise comparison among the attributes as provided by one of the experts surveyed and not a composite mean of all the survey feedback. The feedback received from the other evaluators was analyzed in a similar fashion and all the results obtained were used as a part of the final research result. Table 4 depicts the final ‘overall rankings’ of the identified risks based on a composite analysis of the responses provided by all the experts along with their mean and standard deviations.

TABLE 4. FINAL AHP VALUES OF THE SUPPLY CHAIN SUSTAINABILITY RISKS AND THEIR RANKING

	Supplier	Human Resources	EOL / Waste	Logistics	Legal
Mean Value	0.533	0.238	0.137	0.051	0.043
Std. Dev	0.044	0.016	0.051	0.023	0.009
RANK	1	2	3	4	5

As seen from Table 4, the risks associated with supplier selection was considered as the most important risks associated with supply chain sustainability of an organization. In the current study the *supplier risks* (Mean value of 0.533) was the biggest roadblock for maintaining a sustainable supply chain. This did not come as a surprise since review of literature on supply chain sustainability has repeatedly pointed towards the importance of supplier selection in design and maintenance of a sustainable supply chain. Therefore, wrong decisions regarding supplier selection can lead to a heavy compromise in the sustainability of an organization’s supply chain. In literature review, it can be seen that the influence of supplier is overwhelmingly strong which has led to inclusion of “characteristics of suppliers” as a “building block” in the model of sustainable supply management [20]. Furthermore, in Ansari et al paper “supplier” concept gets mentioned four times as part of sub-enablers. Delphi study, as conducted by [7] also identifies supplier management as one of the four major headings. This study reiterates the paramount importance of supplier selection in sustainability theory.

The risks associated with *human resources* and *end of product life cycle /waste management* were the next most important risks as indicated by their mean. Furthermore, a low value of standard deviation indicated that the respondents were fairly in agreement with each other, in spite of being surveyed separately. It should be repeated that the set of the identified and enlisted risks in the research are under no capacity a holistic set of risks attached with an organizations’ effort to achieve sustainability in its supply chain. Rather, they can be stated as a set of important risks that should be considered while evaluating supply chains sustainability and in turn, formulating risk mitigation strategies. The set of risks provided can be modified, expanded or reduced depending upon the nature of the business process logistics of the enterprise in question. Finally, it should also be mentioned that the relative importance of the risks as exhibited in Table 4 could also vary depending on the prevailing business environment and the circumstances facing the enterprise pursuing to achieve sustainability in its supply chain.

V. CONCLUSIONS AND FUTURE RESEARCH

This paper shows how AHP can be used to identify and rank the key risks associated with supply chain sustainability. Risk identification and analysis are important part of an effective supply chain management functioning. These results can benefit the decision makers responsible for this type of project by focusing their analysis and planning to determine the most effective operational plans by the various alternatives available. Additionally, AHP goes beyond financial analysis by integrating quantitative and qualitative considerations as well as competing stakeholder inputs into setting priorities, which makes it more flexible in nature.

Future research could involve breaking down the identified risk attributes into a set of sub-attributes, in the process forming a second level of hierarchy that might prove to be useful in ranking the risks. Additionally, breaking down the sustainability risk attributes by different industries (and ranking them for different industry) will add considerable external validity to the research process. Finally, verifying the research using other multi-criteria tools like utility analysis or Analytical Network Process (ANP) [26] might prove useful by not only validating the research, but also by adding more robustness and authenticity.

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