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GREEN SUPPLY-CHAIN MANAGEMENT: A COMPREHENSIVE REVIEW

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ABSTRACT:

Environmentally sustainable options are becoming more important in supply-chain management research and practice. A review of the literature reveals that a comprehensive framework for green supply-chain management (GrSCM) has not been established enough. Regulatory agencies that create rules to address social and environmental issues. Its absence makes it difficult for businesses and the economy to develop. A brief summary categorization system to aid academics, researchers, and practitioners in comprehending from a broader viewpoint, a more integrated GrSCM is required. Furthermore, there is adequate literature available to justify a categorization like this. This paper has a new and integrated appearance to it. GrSCM is a field that I'm interested in. The literature on GrSCM is extensively documented from its inception. Conception, focusing on reverse logistics' approach. Taking use of the vast amount of information accessible the literature, particularly older evaluations with restricted viewpoints, the literature on the issue context in the main influential supply chain is used to classify GrSCM. It's also divided into categories based on the technique and strategy used. The following are some of the mathematical tools/techniques that have been utilized in the literature in relation to the settings of GrSCM. mapped. As a quick reference, a chronology with important articles is also given. Finally, the major research problems and conclusions are presented, as well as the advantages are emphasized.

KEYWORDS: *Green Supply Chain, Green Design, Industrial Ecology, Industrial Ecosystems, Waste Management*

1. INTRODUCTION

Operating managers were only engaged at a distance in early environmental management systems. Environmental excellence was ensured via separate organizational units in product development, process design, operations, logistics, marketing, regulatory compliance, and waste management. This is no longer the case**[1].** As with the quality revolution of the 1980s and the supply-chain revolution of the 1990s, best practices now demand that environmental management be integrated into continuing operations. Green supply-chain management (GrSCM) is gaining popularity among operations and supply-chain management academics and practitioners. GrSCM is becoming more important as the environment continues to deteriorate, as shown by decreasing raw material supplies, overflowing waste sites, and rising pollution levels. It's not only about being environmentally conscious; it's also about making smart business decisions and increasing earnings. It is, in reality, a corporate value generator rather than a cost center. GrSCM is also driven by regulatory obligations and consumer demands**[2].**

As a result, GrSCM's scope spans from reactive monitoring of basic environmental management programs to more proactive measures performed via the different Rs (Reduce,

Re-use, Rework, Refurbish, Reclaim, Recycle, Remanufacture, Reverse logistics, and so on). There is enough material on different elements and features of GrSCM. GrSCM. For example, exclusively looks at advances in the area of industrial ecology, while only looks at green design. Much of the research is empirical, and it does not devote enough attention to modeling and network design problems and practices**[3].**

Our goal is to provide a complete, integrated view of the available literature on all elements and dimensions of GrSCM from a "reverse logistics" perspective, in order to aid future study, practice, and research. In order to achieve this goal, we define a few key terms in this section. These have either been obtained from the literature or we have defined them properly**[4].**

The research technique used is described in the second part. The available literature was classified using qualitative analysis based on the issue context and methodology/approach used. We also connect the tools/techniques to the categorization of the issue situation. Finally, for the advantage of academics, researchers, and practitioners, we offer a chronology highlighting important articles. We make some findings and highlight possible problems and possibilities in the field of GrSCM towards the end of the article. Green supply-chain management may be traced back to both environmental and supply-chain management literature. Addressing the impact and connections between supply-chain management and the natural environment is part of adding the "green" component to supply-chain management**[5].**

The limit of GrSCM, like that of supply-chain management, is determined by the investigator's objective. The literature offers a wide variety of definitions and scopes for GrSCM, from green buying to complete green supply chains running from supplier to producer to consumer. GrSCM is described as ‘integrating environmental thinking into supply-chain management, encompassing product design, material sourcing and selection, manufacturing processes, final product distribution to customers, and product end-of-life management after its useful life' for the purposes of this study. We concentrate on elements of RL and mathematical modeling in order to enable future research and study. Green design is a term that has been widely used in the literature to describe the process of creating goods that are environmentally friendly**[6].**

During new product development and process development, it involves the systematic examination of design problems related to environmental safety and health throughout the whole product life cycle. Its scope includes environmental risk management, product safety, workplace health and safety, pollution avoidance, resource conservation, and waste management, among other fields**[7].**

Once the design has been completed, green operations refer to all elements of product manufacture/remanufacture, use, handling, logistics, and waste management. Green manufacturing seeks to minimize environmental impact by using suitable materials and technology, while remanufacturing is an industrial process that restores worn-out goods to like-new state. RL is defined by Rogers and as ‘the process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal,' whereas waste minimization is defined by A literature review seems to be a viable method, since it is a crucial step in defining a study topic and is an essential component of any research project .This aids in the identification of the field's conceptual substance and provides direction for theory development**[8].**

Our study is guided by theoretical preconceptions and follows a well-defined procedure, allowing us to make conclusions based on the examined literature. In framework for doing and assessing research, it may be classed as an archival research technique. Empirical studies

primarily addressing firm-level or particular operational problems were omitted from the review to keep the number of publications down. Similarly, the study omitted highly technical work on issues including life-cycle assessment, inventory, pollution control, and disassembly. Green buying, industrial ecology, and industrial ecosystems were also excluded from research with a strong ecological focus rather than a supply chain focus. This seems to be acceptable in light of the stated goal, which is to integrate environmental considerations into supply-chain management. We cross-reference the published literature from 1990 onwards to find additional studies**[9].**

Because the published literature is so interconnected, one article stem may lead to others branches. As a result, when we take up one thread, we may discover others. As we collected additional references, we discovered that some were more important and helpful than others. Such references are regarded as seminal articles. These were also discovered to be mentioned in the literature a number of times after that. As a result, this study combines and advances the literature on GrSCM from its conception, as described by our goal. Green design may be seen from the perspective of environmentally aware design, taking into consideration the product's or process's lifetime. Similarly, green operations include all operational aspects of RL and network design (collection; inspection/sorting; pre-processing; network design), green manufacturing and remanufacturing (reduce; recycle; production planning and scheduling; inventory management; remanufacturing: re-use, product and material recovery), and waste management (reduce; recycle; production planning and scheduling; inventory management; remanufacturing: re-use, product and material recovery) (source reduction; pollution prevention; disposal).

We specifically exclude literature and practices relating to green logistics since we believe the problems are more operational than strategic in nature and may not be relevant to supply chain design in general. We also don't go into great depth on empirical studies on GrSCM and literature on green buying, industrial ecology, and industrial ecosystems since our study methodology prevents us from doing so. We place a greater emphasis on RL since efficient and effective RL networks are required for efficient and lucrative recycling and remanufacturing. We also put a greater emphasis on mathematical modeling. So yet, none of them have garnered much attention in the GrSCM literature. The categorization is intended to make it simpler to comprehend the many issue contexts of GrSCM – their interactions and connections, so that a well-defined and clear picture can be presented for future study and research. It is not strict, and there may be many overlaps (reduction, for example, is discussed not just in green manufacturing and re manufacturing, but also in reverse logistics and waste management; green design, too, stresses the use of less virgin material and other resources).

Similarly, green design should include all costs associated with a product's life cycle, including those associated with production, remanufacturing, reverse logistics, and disposal. The image provides a simplified perspective that does not account for all of these intricate connections and interactions. We also don't present certain other important elements and topics, such as green buying, industrial ecology, and industrial ecosystems, since our study approach excludes them. The early literature, like in any new study field, emphasizes on the need and significance of GrSCM, specifies the meaning and scope of different terminologies, and proposes methods to further investigate the subject. The fundamentals of greening as a competitive strategy are as follows: Their fundamental argument is that investing in greening may save resources, reduce waste, and increase productivity. In GrSCM, three methods are suggested: reactive, proactive, and value-seeking. In the reactive strategy, businesses devote little efforts to environmental management, begin labeling recyclable goods, and utilize "end of pipeline" activities to reduce production's environmental effect. In the proactive strategy,

they begin to anticipate future environmental regulations by making a small resource commitment to begin product recycling and green product creation.Fig.1illustrates the different processes involved in green supply chain management.

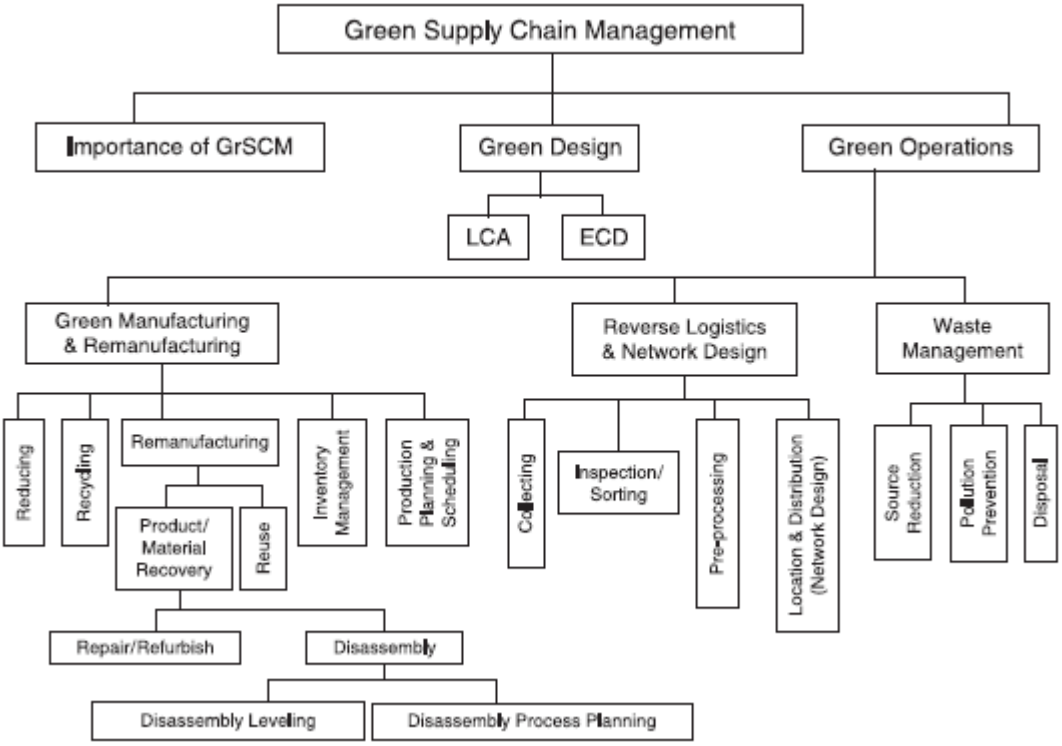

Fig. 1: Illustrates the different processes involved in green supply chain management[10].

2. DISCUSSION

Environmental activities like as green buying and ISO implementation are integrated as strategic objectives within the value-seeking approach's business plan. The emphasis shifts from environmental stewardship as a cost to environmental stewardship as a possible source of economic advantage. The future research topic has been defined as bringing interactions among different stakeholders on integrated GrSCM and the benefits that may accrue to them into the mainstream. Advocates for the development and deployment of new performance measurement systems in a research connecting GrSCM components with performance measurement. He proposes that the supply chain's conventional performance assessment framework be expanded to incorporate methods for product recovery. Manufacturing that incorporates recycling is referred to as recycling-integrated manufacturing.

Automobiles, electronics, and tires are among of the industries that use re manufacturing. Product recovery is a wide term that refers to a collection of actions aimed at recovering value from a product that has reached the end of its useful life. Resource recovery alternatives using mathematical models. Various writers define and categorize the recovery process in various ways. Recovery is divided into repair, refurbish, remanufacture, cannibalize, and recycle as a mix of remanufacture, re-use, and recycling. Provide appropriate concepts and vocabulary as well as recovery methods. A methodology for assessing product recovery methods without breaking physical and economic feasibility limitations has been developed and explored. Models for periodic and continuous reviews have been created. A model in which returned products can be re-used directly, a model with a holding cost, a model with

variable set-up numbers, and models considering the effects of non-zero lead-times are all examples of periodic review models that find an optimal balance between inventory holding cost and production cost.

A model for a remanufacturing system with non-zero lead times and a control policy based on the conventional (s, Q) rule is presented, as well as an alternative approximation technique. Develop push and pull methods for combined manufacturing and inventory management for a system that uses new and recovered components. In-depth discussion of RL inventory models. A lot of work on quantitative methods in RL has been published in recent years. A cost-minimization model for a multi-time-step, multi-type hazardous-waste RL system is presented in the RL system planning for recycling electrical appliances and computers. They illustrate the viability of their suggested method by presenting application examples. An integrated framework for modeling the RL network of electronic trash, which includes recycling as well as three kinds of rework facilities. They illustrate the viability of their suggested method by presenting application examples. A comprehensive framework for modeling the RL network of electronic trash, including recycling. A stochastic programming-based method for explicitly accounting for uncertainties in a deterministic location model for product recovery network design.

They apply it to a realistic real-world case study in the Netherlands involving the recycling of sand from demolition debris. Their analysis of the data provides valuable insights into decision-making in uncertain situations. For a single period, model, they calculate the optimum order quantity based on the demand distribution, the likelihood of a sold product being returned, and all related revenues and expenses. For integrated GrSCM, only a few models have been utilized. The following methods have been tried: AHP/ANP, regression, DEA, and descriptive statistics (based on surveys/interviews). Linear programming, non-linear programming (NLP), and mixed integer linear programming (MILP) have also been proposed in publications but have not been widely utilized. In terms of mathematical tools, methods, and processes, green design has seen relatively limited use. Recently, LP, MILP formulations, software programs, and spreadsheets have been utilized to solve problems. Mathematical models, tools, and methods have been utilized to a far greater degree in green and sustainable manufacturing. MILP, simulation, computer programming, software packages, spreadsheets, and dynamic programming were all heavily used. Simulation, Markov chains, algebraic equations, ANOVA, heuristics, meta-heuristics, and regression are some of the other conventional tools and methods that have been utilized.

There have also been experiments with fuzzy thinking, neuro-fuzzy reasoning, and game theory. The main method in production planning and control is to define issues using priority criteria, followed by simulation to provide descriptive statistics for analysis. For input, interface, and calculations, computer programming and software packages were utilized. When inventory management, waste disposal, and economic concerns are taken into account, dynamic programming is utilized. The use of EOQ-type algebraic equations is common in inventory management. Reverse logistics models are based on conventional location and layout models and focus on network design issues. The usage of computer programming and software tools is on the rise. LP, NLP, and MILP are the most common problem formulations. In RL and remanufacturing systems, dynamic programming has been utilized. The waste management models are typically conventional models with disposal choices. Too far, GrSCM research has been segmented into subject categories based on operations strategy. Quality, operations strategy, supply-chain management, and product and process technologies have been the main focus areas, and they are all starting to contribute to a more structured knowledge base. In the near term, it is fair to anticipate that these study fields will

continue to offer the most potential for advancement. Longer-term, more integrated contributions, such as intra- and inter-firm dissemination of best practices, green technology transfer, and environmental performance assessment, are required.

3. CONCLUSION AND IMPLICATION

GrSCM can decrease industrial activity's environmental effect without compromising quality, cost, reliability, performance, or energy efficiency. It requires a paradigm change, from end-of-pipe management to satisfy environmental laws to a scenario where environmental harm is minimized while total economic benefit is realized. Practitioners, academics, and researchers face a variety of difficulties in this field. We provide a current literature overview on GrSCM that encompasses the whole range of activity in the field. The continuing integration process in GrSCM is highlighted in our literature study. We discovered that the level of study in various areas varied. Many particular empirical investigations have been conducted, and categories like remanufacturing have been thoroughly investigated. Even within remanufacturing, disassembly has been well investigated. Other categories, such as RL, have recently gotten greater attention. We concentrate on less-explored areas since they have the potential for future investigation and study. Academicians, practitioners, and researchers will benefit from our categories since they will help them comprehend integrated GrSCM from a broader viewpoint.

An evolutionary chronology has been created based on our issue context categorization and scope for future practice and study, taking into consideration all important and seminal articles published in the field of GrSCM. Figure 2 shows the same thing. Our categories, as well as the chronology and referenced sources, may be used to create ideas and models that help managers and other stakeholders attempt to incorporate ecologically sound decisions into supply-chain management. By consulting empirical research, practitioners may get a better understanding of real-world issues and how certain businesses have attempted to solve them. This may be used as a springboard for people to adapt and create their own ideas and activities. The product life cycle has been extensively researched. However, additional study is required to fully comprehend RL and its relationship to the product life cycle.

An essential topic for research would be to examine how, in reality, RL activities alter throughout the course of a product's lifetime. More information on the levels of returns is required. On a fundamental level, there isn't much information available on product return rates by product category. More research on the effect of marketing on returns is required. To establish the connection between new product sales and return rates, theories and models must be created and consolidated in general. There is a need for further research on how businesses should handle, store, and dispose of returned items. Understanding secondary markets and how businesses can effectively sell unwanted goods requires a lot more study. Many companies are now selling this material via online and conventional auctions, in addition to traditional brokers.

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