Justifiable Logistic Network Management: A Production Model for Optimizing Energy Use, Cost, and Carbon Radiations

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Abstract— Automating the manufacturing process is a top priority for many businesses today because it allows them to increase output while maintaining quality, which is essential for quickly responding to client demands. This pattern has resulted in a progressive shift in technology, with the inevitable consequence of a rise in energy demand. In order to prevent the need for increased energy consumption for improved manufacturing technology in industrialized countries, academics have begun working on continual development in conjunction with cleaner-energy regulations. In addition to nuclear weapons, global warming caused by human-produced greenhouse gases is another major problem in our society today. So as to make up for the energy need and lower the carbon balance for cleaner manufacturing, renewable energies like insolation have expanded rapidly in recent years. This paper discusses the Logistic Network management of the automotive industry with its suppliers in order to maximize production while simultaneously minimizing costs, reducing carbon exhalation and making the most of renewable energy sources. This analysis considers a scenario where providers monitor and control faulty products as an outsourced service. The suggested mathematical model considers sustainable suppliers and is solved using a loaded goal programming approach. The model's responsiveness to changes in energy use is evaluated across a range of scenarios. Documentation of successful down-to-earth use in the automotive industry includes minimum production costs and carbon emissions. Considering the manufacturer and suppliers, the results verify the model's potential to provide a foundation for sustainability in the logistics network environment.

Keywords: Carbon exhalation, Energy sources, Production model, continual development.

I. INTRODUCTION

The primary focus of manufacturing companies is on reducing production costs. Similarly, numerous researchers have optimized production models by lowering total production costs and considering acceptable, free products [1-6]. Customers' growing interest in environmentally friendly goods has prompted several industrialized nations to implement new rules and methods to achieve acceptable production. However, manufacturers have an opportunity to implement the concept of sustainable development through research because emerging countries face international market rivalry due to a shortage of sustainable products. Efforts at the production, processing, and system levels and the entire supply chain are required for such sustainable production.

In its 1987 report, the Burundian Commission defined sustainable development (SD) as an approach to meeting the demands of the present without sacrificing the ability of future generations to do the same [7,8]. Energy's potential to serve as a driving force in progress makes it a crucial barometer for tracking the long-term health of industries and communities alike [9]. The growing global population and the rapid development of related technologies drive an ever-increasing energy need. The industrial sector consumes a disproportionately high amount of energy, contributing significantly to the world's total energy consumption. Table 1 shows the results of the U.S. energy information administration's analysis of global energy use from 2012 to 2040. Global energy consumption is predicted to rise at a slower annual rate of 1.2% until 2040, when it will have caught up with but still been behind that of natural gas. But the analysis's bright spot is the renewable energy sector's 1.3% annual growth, which is higher than the norm but lower than natural gas's 2.5%. Sustainable development, through the design of environmentally friendly productions and processing in the manufacturing sector, along with social assistance, reduces carbon emissions even more, accounting for a larger percentage of the total [10]. Carbon emissions taxes, carbon exchange, and carbon emissions trading are only a few of the many laws and regulations passed at the national level [11,12]. For the sake of humanity and the planet, we need to update our technology policies in order to improve the efficiency of our energy use and cut down on our carbon output.

Energy Source	2012	2020	2025	2030	2035	2040	% Change Annually
Total World	222.3	245.8	262.6	278.0	294.0	309.1	1.2
Liquid fuel	66.5	72.2	76.5	80.6	84.6	88.6	1.0
Natural gas	50.7	56.2	62.0	68.0	74.5	80.4	1.7
Coal	55.7	62.0	64.3	66.0	67.2	68.7	0.8
Electricity	31.9	37.2	40.0	42.2	44.3	46.3	1.3
Renewable	17.4	18.2	19.7	21.3	23.0	25.1	1.3

Table 1: Data on energy usage in the global industrial sector from 2012 to 2040 (quadrillion Btu)

Greenhouse gas emissions (GHG) caused by burning fossil fuels have harmed the ecosystem because of rapid development and rising population. In an effort to maintain a healthy ecosystem and preserve natural resources, businesses are developing methods to reduce their energy use and carbon footprint. While these regulations may be well-intention-ed, the investments they entail increase consumer prices. Therefore, choosing a renewable energy source to meet the necessity of both present and forthcoming generations is a critical issue [13]. One of the world's biggest problems is getting people reliable access to energy. However, solar energy may be the most viable choice due to its widespread availability [15]. The efficiency and adaptability of silicon technology have made solar cell designs quite popular. Cells in photovoltaic (PV) systems capture sunlight and use it to generate power [16]. Branker et al. [17] analyzed the break- even cost to generate the energy for solar power through a case study depend on the Ontario Power Authority in Canada. We find that the high up-front cost of PV perhaps mitigated through a combination of low-interest, long-term financing and a high discount rate.

To mitigate the impact of excessive energy use, businesses can also examine their products during the time that level. An essential part of green manufacturing, sustainable machining seeks to lessen the negative effects of conventional machining on the atmosphere by cutting down on its energy use, waste output, and price. Arctic machining, dusty machining, and near dusty machining (also known as minimum quantity lubrication [MQL]) are all examples of sustainable machining [18]. When MQL is utilized in manufacturing, it significantly helps cut down on wasteful emissions and power use. MQL's primary goals are to reduce friction and improve product quality. An MQL system reduces waste, lengthens the useful life of tools, ensures the health and safety of employees, and reduces energy consumption in machine tools. Figure 1 shows a component's machining expenses (energy, soluble oils, pointed tool, waste, etc.). These findings highlight the need to consider cutting fluid cost, which is significantly higher than that of the pointed tool mounted in a machine tool at 15%. That's why, for sustainable machining, it's crucial to use MQL and reap the economic, environmental, and social benefits it brings to the workplace.

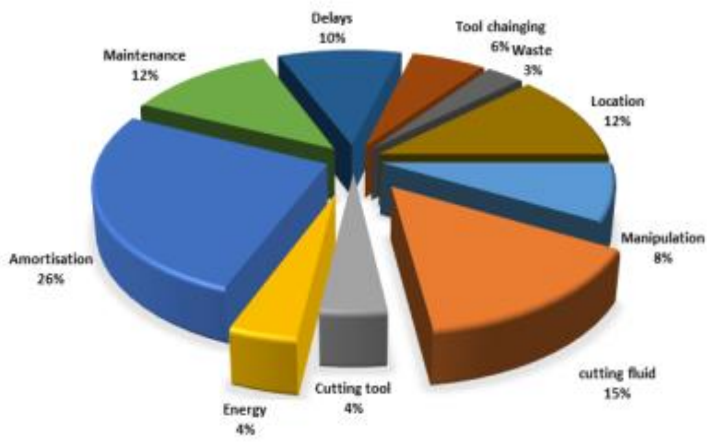

Figure 1. Breakdown of Machining cost

The research presented here represents progress toward justifiable development in the manufacturing sector by using MQL at the development smooth and cleaner-energy technologies throughout the manufacturer-supplier supply chain. The primary result is an estimate of how much of a carbon balance can be reduced by the use of renewable energy. The research lays the groundwork for the car parts industry to switch to sustainable energy as a power source for long-term viability in production. These real benefits to the environment will help policymakers worldwide see how renewable energy may assist them meet the production and logistic network management challenges posed by climate change. Specifically, the document is organized as follows: In Section 2, we will discuss the literature on topics such as sustainable energy, carbon balance, and sustainability. In addition, a new version of weighted multi-objective goal programming (WGA) is demonstrated for discussion of the model in Section 3, which details the development about mathematical model taking assumptions into account. The suggested goal-oriented paradigm is verified in Section 4 with a numerical example and Section 5 with findings. In Section 6, we offer the model's sensitivity analysis for exploring the impact of energy consumption on supply chain manufacturing systems. The final section of the paper discusses the findings.

II. LITERATURE REVIEW

The amount of energy used is a major factor in LCA analyses. During the production phase of LCA research, there is sufficient data on energy consumption to make a number of educated guesses. Statistics show that 90% of industry's overall energy use goes toward the manufacturing sector. There is growing interest in sustainable production due to Earth's finite and dwindling energy resources. Sustainable production practices, including energy efficiency, attempt to process products using energy exhausted and the smallest possible carbon footprint. Effective efforts were made by Akpunar et al. & Bortolini et al. to reduce the overall energy required for transporting AS/RS. Sustainable energy is expected to play a pivotal role in resolving energy demand and environmental concerns. LCA-based approaches determine the energy time to pay up, net energy ratio, CO_2 emissions. Alsema determined the amount of energy needed and the amount of CO_2 released during production of the grid-connected system. In Gobi Desert of Mongolia, Ito et al. have successfully studied the cost and biorhythm of solar systems with a capacity of 100 MW. Carbon footprint (CFP) measurement methods are the most effective for reducing greenhouse gas (GHG) exhalation. Evaluation of greenhouse gas radiation throughout wheel of life, from resource extraction to final delivery, can be conducted with help of CFP, which is depend on the wheel of life concept. Accorsi et al.& Lerher et al. aim to minimize the system's total value and carbon footprint when planning the manufacturing system's warehouse layout.

High electricity consumption from machining is cited as the primary reason manufacturing automation negatively affects the environment. Utilizing the Taguchi design technique, Sarkaya and Gu llu 'concluded that MQL is superior for machining operations to preserve cutting component surface quality. Cutting fluid accounts for 7-17% of production costs, far greater than the 2-4% that cutting equipment accounts for, according to a survey conducted among German automakers. Hadad and Sadeghi applied MQL to the turning process analysis, assessing its efficacy in terms of force, material roughness, and temperature distribution. However, MQL must be considered in manufacturing and production models for environmentally responsible machining.

Standard production models for manufacturing systems assume perfect quality products with consistent demand. However, in practice, it is impossible to always act in accordance with the best-case scenario assumptions. No manufacturing system can reliably turn out flawless products due to factors such as wear and tear on machinery, occasional breakdowns, and human mistake. This is why academics have gone above and beyond the original models by factoring in the possibility of faulty manufacture. With defective products in mind, Kim et al. devised a model for a multi-stage production system. An EMQ model for defective production with rework and different delivery strategies was also created by Ca'rdenas-Barro'n et al. The consequences of reliability and inflation were accounted for when Sarkar et al. derived their economic manufacturing quantity (EMQ) model. Sarkar and Moon introduced an EPQ model that accounted for inflation within a flawed production system to maximize the profitability function of production. Lean production in a production system was studied by Tayyab and Sarkar, who considered a random defect rate. Researchers also did a lot of work to construct various mathematical models that took energy consumption and carbon footprint into account using a wide variety of analytical methods. Soroudi et al. built a multi-objective model approach for a distributed energy network's growth based on the immune genetic algorithm (I-GA) to reduce expenses and carbon emissions. Kahraman et al. identified the most promising renewable energy resource alternative (AHP) using a fuzzy-based inter tool and an analytical hierarchical approach. In order to find the highest power point of photovoltaic solar cells, Zagrouba et al. used GA to analyse their electrical characteristics. Utilizing optimization methods, Kulkarni et al. calculated how much money could be made from recharging water supplies. Few studies have accounted for manufacturers' carbon footprints in supply chain models. To reduce manufacturing and retail establishments' carbon footprints, Xiao et al. optimized a supply chain. To help with decision-making under uncertainty, Wu and Chang have proposed a grey theory that factors in environmental impact in the form of tax during the production planning stage. A multi-objective model is created by Wang et al. to assess the cost-benefit analysis of following environmental rules in green supply chain. Wang et al. (2016) propose an electricity monitoring system that considers multi-objective linear programming & carbon footprint. To reduce manufacturing expenses, the authors looked at the process of making automobile parts while also considering the impact on the environment and the price of power. Electricity, diesel, & gasoline were the primary fuels.

However, the impact of renewable power on the total costs and carbon emissions of a manufacturing system has not been quantified in prior research. In this study, we build on the model of Wang et al. to create a model with several, interrelated goals. Incorporating renewable solar energy, environmental cost (tax), & minimum quantity lubricant at advance level in the manufacture of the automobile component elements industry connected with suppliers within supply chain is the paper's key contribution. Experts and practitioners in the field of supply chain management agreed that the idea of a carbon tax and the levelized demand of solar energy offered positive economic benefits. For sustainable manufacturing, the concrete outcomes are traded off against production costs in favour of reduced carbon emissions. Product design, manufacturing, & supply chain all need work or optimization for such a healthy manufacturing environment. For the sake of realism, the given model also considers a situation in which providers within supply chain manufacture faulty things. To achieve sustainable manufacturing within supply chain and reduce overall production costs, carbon radiations, and energy expenditures, we employ the weighted goal programming (WGP) method to determine the best allocation policy for making automobile parts.

III. MATHEMATICAL MODEL

The ecological toll of energy sources has been estimated using mathematical models. Formerly, managers were content to concentrate on the three primary goals of price, time, and quality. Present and projected global warming scenarios have prompted scientists and experts to establish an environmentally sustainable goal. This is why supply chain management also manufactures and addresses issues related to sustainable components, such as energy use and carbon emissions. This paper discusses multi-objective goal programming as it relates to the logistics network management of a Taiwanese car part's integrated suppliers in the time of manufacturing phase. Integrating sustainability suppliers to take on the restrictions of carbon footprint with renewable energy, as indicated by the mathematical model, extends the model's significance beyond the production system. Taiwan is well-known among-st emerging markets as a producer and supplier of a wide range of automobile components. Car part assembly follows a two-stage production flow diagram, as shown in Figures 2 and 3.

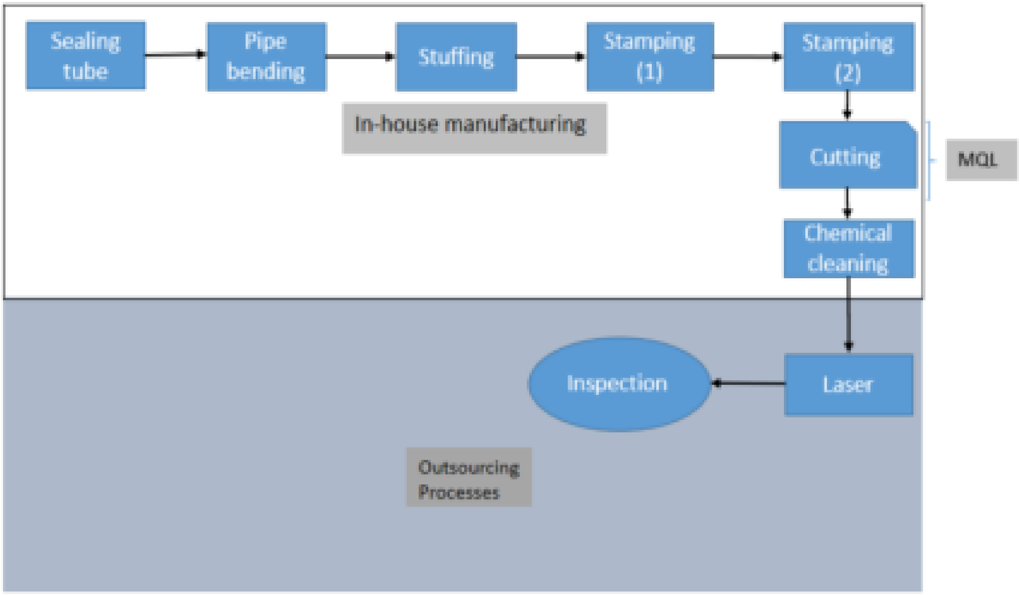

Figure 2. Auto component manufacturing process flow.

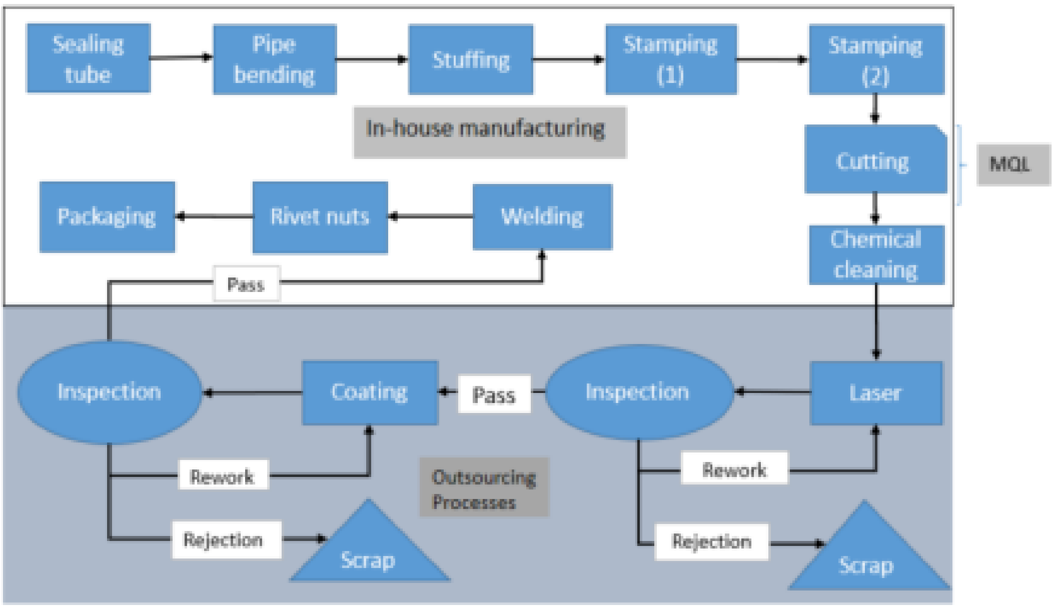

Figure 3. Auto component manufacturing process flow.

Sealing, bending, filling, stamping 1 & 2, cutting, polishing, laser, coating, welding, attaching, and packing are only some of the steps in the assembly process for the three components A, B, and C, all of which take place in-house. Electricity, solar power, fuel, and gasoline are all used in production operations. Consider a scenario in which solar power, as a renewable resource, provides h percent of the electrical needs. Taking this into account reduces the electrical demand for each process category to 1h. The levelized energy cost (LEC) generation is used to compare solar energy's economic viability as a renewable with those of other electricity technologies. Through discounted cash flow approaches, such as determining the cash flows by means of a discount rate, r, LCOE determines the annual price of solar energy while considering the solar system's life time. Therefore, in Equation (1), the current valued net costs should equal the sum of the discounted LCOE times the energy produced.

$$\sum_{t=1}^{T}\left(\frac{LCOE_t}{(1+r)^t} \times E_t\right) = \sum_{t=1}^{T}\frac{C_t}{(a+r)^t}$$

where C_t is the total price of the solar power system, including all expenditures such as initial investment (I_t), operating costs (O_t), maintenance costs (M_t), and fuel costs (F_t) as shown in Equation (2).

$$LCOE = \frac{\sum_{t=1}^{T}(I_t + O_t + M_t + F_t)/(1+r)^t}{\sum_{t=1}^{T} E_t/(1+r)^t}$$

Manufacturers often contract out coating & laser operations to third parties like U, V, and W due to resource constraints and the desire to keep costs down. After each laser & coating process, items are brought to an inspection station to be sorted into pass, remodel, and rejection piles. When a part is evaluated, it either moves forward into the next station, is sent back to be reworked, or is sent to the scrap section, where it can be sold for scrap metal. Let denote the percentage of defective items in production, percentage of scrap in defective items, the scrap quantity in production, and the rework parts that were brought back to the same workstation. When considering which suppliers to outsource to, manufacturers look at three factors: price, quality, and environmental impact. In order to improve the process flow on all fronts (environmental, social, and economic), it is proposed to use cutting fluid instead of MQL during the cutting operations. The optimal solution about a multiple objective mathematical model expressed as the system of equations can be found using a variety of methods. A popular approach to making decisions based on multiple factors, goal programming (GP) was created by Charnes et al. GP's primary idea is to develop a solution that is as close as available to each desired outcome. Due to this, a value indicative of the degree to which each goal has been met is obtained. Different amounts of deviation are assigned to different variables to illustrate how far the actual outcomes lie outside or inside the specified parameters. WGP aids decision-makers in achieving the most essential purpose of the desired aims by assigning weights of objectives and play down the total price in the shape of devotional variables.

IV. NUMERICAL EXAMPLE

We demonstrate the practical use of the suggested mathematical model via a numerical challenge. Research data, with the exception of solar power, the MQL method, and scrap, was primarily gathered from the investigation of Wang et al. A network of machine instruments and an electrical monitoring system were combined to keep track of the duration and variables of manufacturing processes. The operations' electricity usage was gathered from the units provided by electric meters, at the same time that the operations' gasoline and diesel consumption were gathered from historical records. Information on outsourcing and rework was gathered from suppliers. The production system costs and requirements are listed in Table 2. Manufacturing, upkeep, storage, scrap, and material quality loss (MQL) are all significant fixed and variable expenses. Manufacturing costs for Items A, B, and C were estimated to increase by a total of m% due to MQL system costs. It has been stated also coolant management costs account for anywhere from 7.5% - 17% of total manufacturing costs, with the average being 12.25%.

Cycle Time	Item Type	Fixed Cost ($/Cycle)	Manufacturing Cost ($/Unit)	Crashing Cost ($/Unit)	Holding Cost ($/Unit)	Maintenance Cost ($/Cycle)	MQL Cost ($/Unit)	Warehousing Cost ($/Unit)
1	*A*	2307	0.32	0.42	0.25	510.5	0.0725	0.067
2	*B*	2307	0.29	0.39	0.21	255.26	0.0725	0.08
	C	2780	0.18	0.23	0.04	574.33	0.0725	0.13

Table 2. Manufacturing data.

Table 4 displays reworking cost & scrap cost. We estimated that the average scrap cost per unit produced would be $0.083, or nearly 3% of the total price of production. Costs and carbon intensity ratios for several fuels and energy sources, including gasoline, diesel, solar, and electricity, are listed in Table 3. Residential rooftop (below 20 kWe), business rooftop (from 20 kWe - 1 MWe), & large ground mounted are the three primary types of PV systems based on energy generation (more than 1 MW). The utility-scale Planetary system is being considered for power generation to meet the h% necessity of power from solar. They function similarly to other power plants by adding to the national grid. Thousands upon thousands of these solar power plants have gone live around the globe. From the statistical investigation report of IRENA depends on the universal energy data, the average LCOE is estimated to be 0.195 $/kWh (average of 0.11-0.28) (assuming life period = 25 years, concession rate = 7%, accommodation factor = 12%, yearly efficiency = 12%). Cost per kilowatt-hour (kWh) overnight = $7284; cost per kWh (in capital expenditures) = $754. As an incentive for businesses to reduce their carbon footprint, the government charges firms $25 each metric ton of CO_2 they release into the atmosphere. Based on their findings, estimate that the PV system's total life-cycle carbon emissions will cost 32 CO_2 $/kWh. Manufacturing system and warehousing capacity limitations owing to limited resources.

Energy Source Type	Unit Cost ($)	$kgCO_2e$	Cost of CO_2 ($/kg)
Electricity (kWh)	0.1	0.536	0.025
Diesel fuel (L)	1.06	2.615	
Gasoline (m^3)	0.6	1.881	
Solar energy (kWh)	0.195	0.032	

Table 3. Energy cost & carbon emissions

Table 4 displays information gathered from surveys and surveys about manufacturing, modification, and outsourcing businesses' use of electricity, diesel, photovoltaic, and gasoline. Adding solar energy, a sustainable energy source, through production system is being examined to decrease the system's reliance on conventional electricity. In the present numerical example, h = 20% of power utilized, so the need of electricity is lowered to 1h in each activity; for example, 0.38 kWh of electricity was used to produce item A. The 0.0636 kWh of cosmic energy joined to the production system resulted in a 0.2544 kWh drop in overall electricity use. Items A and B have identical fuel consumption rates of 0.3184 L for diesel and 0.0004 m3 for gasoline. Information gathered via outsourcing includes supplier capacity limits, the expense of outsourcing, and the percentage of defective or junk goods. It is assumed that there is a 1.2% faulty rate of the goods and a 2% scrap rate into this proposed model to provide a realistic portrayal of the model.

Production Status	Item Type	Electricity (kWh)	Diesel Fuel (L)	Gasoline (m^3)	Solar Energy (h% of Electricity, kWh)
Manufacturing	*A*	0.2544	0.03184	0.0004	0.0636
Manufacturing	*B*	0.2344	0.0937	0.0005	0.0586
Manufacturing	*C*	0.364	0.0718	0.0005	0.091
Reworking	*A*	0.54	0.0055	0	0.135
Reworking	*B*	0.5616	0.0055	0	0.1404
Reworking	*C*	0.6056	0.011	0	0.1514
Outsourcing by *U*	*A*	0.5232	0.008	0	0.1308
	B	0.5096	0.008	0	0.1274
	C	0.576	0.015	0	0.144
Outsourcing by *V*	*A*	0.5784	0.007	0	0.1446
	B	0.5424	0.007	0	0.1356
	C	0.5928	0.015	0	0.1482
Outsourcing by *W*	*A*	0.56	0.01	0	0.14
	B	0.524	0.01	0	0.131
	C	0.5464	0.015	0	0.1366

Table 4. Information on energy use

V. NUMERICAL RESULTS

Manufacturing methods and automation helped elevate the car parts business to the higher level of sophistication. A sustainable & cleaner manufacturing for robust supply chain management requires the aplication of solar renewable power as an origin of energy to produce the vehicle parts. The suggested multi-objective model is formulated as a linear system of equations. A multi-objective problem can be solved in a number of ways, including by a subjective strategy that considers the preferences of the people making the decisions. By assigning a relative importance to each objective, lexicographic programming can keep the number of unwelcome deviations to a minimum. Chebyshev programming aids decision-makers in striking a balance between pursuing a set of objectives and allowing maximum variation in the course of doing so. A key component of weighted goal programming is the ability to prioritize objectives. The proposed model is formulated using weighted goal programming so that decisions can be made based on what will provide the best outcome for a given goal, given the given constraints. Using the MATLAB-16a (United States) tool for linear programming (LP), the ideal results of three goals into the price of production, carbon radiation, and energy cost were estimated as $11333, 1585.67 kg, and $194.51, respectively. With the WGP model, these aims serve as target values; the model makes use of weights to establish the order of importance of the goals. Within this range of values, the positive slack variables of three objectives should be reduced. Total production cost (goal A) and carbon radiations (goal B) can be optimized to a minimum of 104.56 and 65.16, respectively; however, the cost of electricity (goal C) can be optimized to a minimum of 8.85. Implementation of linear programming and WGP yields the optimum solution of decision variables as per production amount, smashing quantity, and allocating quantity. Management will be able to make more informed decisions on how much work should be done in-house, in the cloud, or by outside vendors with the help of these findings. WGP's in-house production and crashing volumes remained relatively constant from their starting points, but the company's outsourced amounts changed substantially. These findings also help manufacturers and suppliers decide on the appropriate manufacturing outsourcing level. A percentage of the electricity used by the vehicle part manufacturing business is coming from solar renewable energy, therefore this shift should have a beneficial effect on the production system's greenhouse gas(GHG) emissions and energy cost. This model provides an optimal allocation approach that considers the constraints of crashing & outsourcing quantity to fulfill the desired demand. Managers and practitioners in the auto parts sector will find the proposed model's vast collection of parameters and accompanying data to be quite useful. Practical applications of photovoltaic in the automotive parts sector have yielded ideal outcomes and solutions. Indeed, the managers are compelled to use the photovoltaic technology to create a new product as a consequence of a green product once the model is validated through a numerical example. These findings, taken as a whole, demonstrate the successful reduction of greenhouse gas emissions in the vehicle part production system and may be heavily included into the decision-making instruments for the assessment of implementing sustainable technologies in supply chains.

VI. SENSITIVITY ANALYSIS

The suggested model's goals of minimizing total production costs, carbon emissions, and energy costs are all affected by how much of the share of energy mix is comprised by solar power. Large sums of money will need to be spent on the solar system up front, but it is predicted that the ongoing expenses of a PV system will be far lower throughout the course of its useful life. Furthermore, in some developing nations, government and environmental organizations are helping to subsidize the proportion of original solar system investment due to its lap of nature and the need to prevent the global warming matter. New studies have shown that the limits on solar systems' capacity and efficiency can be lowered significantly. Nonrenewable energy sources are being phased out in favor of solar energy systems in homes, businesses, and factories. For this reason, extra tests are required to cover various solar system usage cases. The impact of solar energy's substitution for other forms of electricity generation on the target values of total production costs, carbon radiation, and energy cost is investigated through a sensitivity evaluation about the proposed model involving 10 instances. The first four examples all concern how delicately the manufacturing system balances its energy needs. In Table 5, we see four different scenarios that show the facts we need to understand how solar energy and electricity use varies.

Production Status	Item Type	Case 1 Solar $h = 0\%$	Case 1 Electricity $(1-h)\%$	Case 2 Solar $h = 10\%$	Case 2 Electricity $(1-h)\%$	Case 3 (This Paper) Solar $h = 20\%$	Case 3 (This Paper) Electricity $(1-h)\%$	Case 4 Solar $h = 30\%$	Case 4 Electricity $(1-h)\%$
In-house	*A*	0	0.318	0.0318	0.2862	0.0636	0.2544	0.0954	0.2226
In-house	*B*	0	0.293	0.0293	0.2637	0.0586	0.2344	0.0879	0.2051
In-house	*C*	0	0.455	0.0455	0.4095	0.091	0.364	0.1365	0.3185
Rework	*A*	0	0.675	0.0675	0.6075	0.135	0.54	0.2025	0.4725
Rework	*B*	0	0.702	0.0702	0.6318	0.1404	0.5616	0.2106	0.4914
Rework	*C*	0	0.757	0.0757	0.6813	0.1514	0.6056	0.2271	0.5299
Outsourced to supplier *U*	*A*	0	0.654	0.0654	0.5886	0.1308	0.5232	0.1962	0.4578
	B	0	0.637	0.0637	0.5733	0.1274	0.5096	0.1911	0.4459
	C	0	0.72	0.072	0.648	0.144	0.576	0.216	0.504
Outsourced to supplier *V*	*A*	0	0.723	0.0723	0.6507	0.1446	0.5784	0.2169	0.5061
	B	0	0.678	0.0678	0.6102	0.1356	0.5424	0.2034	0.4746
	C	0	0.741	0.0741	0.6669	0.1482	0.5928	0.2223	0.5187
Outsourced to supplier *W*	*A*	0	0.7	0.07	0.63	0.14	0.56	0.21	0.49
	B	0	0.655	0.0655	0.5895	0.131	0.524	0.1965	0.4585
	C	0	0.683	0.0683	0.6147	0.1366	0.5464	0.2049	0.4781

Table 5. Case studies of automotive suppliers' energy use patterns.

Each scenario has a unique solar energy consumption percentage expressed as a decimal (h%) determining the power level needed. Case 1 depicts the viewpoint about Wang et al .'s study, in which electricity is the only primary energy source and no other energy is drawn from solar PV in the production process, whereas Case 3 depicts the starting values as treated in our suggested model, with h = 20%. For both Case 2 and Case 4, solar energy supplies h = 10% and h = 30% of the total electricity needed by the production system. This electricity used over the course of a year is reduced by a single hour in each scenario. The outcomes of linear programming reveal a drastic reduction in carbon emissions (target B) compared to instance 3 (h = 20%). Let's look at Case 1 and compare it to Case 3 (in this paper). We see that the absence of solar power utilization has a negligible influence on total production costs (0.1%) but has a large effect on the cost of carbon dioxide emissions (16.7% and +10.6%, respectively). Even while the outcome is significant for learning about the environmental effects of solar energy's favorable use, it may come at a higher production cost. In Case 4, however, when solar energy utilization is increased by 30%, energy costs rise, causing a nearly 0.04% increase in total price of production. Based on these findings, it can be said that integrating solar energy into the manufacturing process is crucial for the auto parts industry's quest to cut down on its carbon footprint, but it does come at a little cost to overall production prices. Computing the global weighted mean LCOE of convenience range solar systems, i.e., 0.195 $/kWh, includes the higher production costs caused by initial expenditures. Since 2010, the estimated global average LCOE of utility-scale solar PV has dropped by half, bringing it to an all-time low. The most competitive utility-range system may produce power for as little as $0.08/kWh with no subsidies and as little as $0.06/kWh with cheap financing. It is predicted that solar electricity costs would same those of traditional electricity somewhere between 2031 and 2042, at which point the empyreal system will have achieved grid parity. Government actions (to subsidies, less interest rates on loans for PV, enlarge carbon tax, etc.), geography (huge solar expedient), and reduced discount rate can all contribute to a quicker time to grid parity. Manufacturers and consumers that care about the environment can design a strategy that allows them to make trade-offs between the costs and benefits by using renewable energy and eco-friendly products. These findings will help policymakers design plans to increase the use of solar sustainable energy for future generations' benefit and mitigate the effects of climate change.

Additional testing is required to examine the suggested model's sensitivity to changes in energy, carbon radiations, and other primary production costs. The LCOE of solar power system and the price that governments place on carbon emissions vary from one region to the next. The full life cycle cost of manufacturing and associated carbon emissions may also be affected by factors such as inflation, degradability, discount rate, and system efficiency.

VII. CONCLUSIONS

The use of non-refillable energy sources has created an increase in carbon emissions, which is a major contributor to global warming. Because of this, scientists and specialists are trying to find a long-term answer. In order to formulate a production system for both of retailers and manufacturers within a logistic network, this research suggested a multi-objective model to concurrently reduce overall production cost, carbon pollution, including energy costs for manufacturing operations. In order to reduce carbon emissions in the production system, it was discovered that using renewable energy like a cleaner green science had a positive effect on the environment. However, the total price of manufacturing had increased slightly due to early investments of sustainable energy from the lunar system, while operational costs are more manageable. The LCOE outweighs the initial expenditure for solar PV. When it comes to achieving long-term goals for sustainable development, the government's policies play a crucial role by offering incentives & policies to encourage broader use of solar systems. For the government to achieve its energy goals, consumers must also favor sustainable items manufactured with clean energy technologies. Further, MQL implementation at the machining process level is critical for environmentally friendly machining. The recommended goal-oriented exemplary is important for both of manufacturers and suppliers to accomplish legitimate production in respect of MQL & renewable energy by optimizing production costs, carbon emissions, and energy costs with the WGP technique. PV-based energy is not significantly more expensive than other forms of renewable energy, economically speaking. Renewable energy prices continue to drop every year, making it a great option for sustainable production processes. In addition, more study is needed to provide a tool for comparing various energy systems using LCOE. To reduce greenhouse gas emissions, the storage and inventory system must also improve the efficiency of its warehouse operations. More research is needed to reduce the time, money, and effort needed for PV system installation and setup. You can try using a different method if you want more accurate findings from your model analysis. The recommended model can be made more generic by considering production costs as fuzzy, leading to more cost- effective and carbon-footprint-reducing solutions. Air and water-founded technologies, which generate renewable energies, are also crucial for analysis and might be integrated for gap analysis depends on best outcomes. Manufacturing companies can gain an edge in the market by transitioning to low-carbon production methods. Overall, this study will raise awareness among producers about the significance of sustainability amid supply chain stakeholders in respect of sustainable energy, carbon emissions, and MQL to meet the expectations of modern consumers for sustainable products.

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