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ORIGINAL ARTICLE

# The effect of green supply chain management practices in reduction of construction wastes and carbon emission in Bangladesh

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## Abstract

The environmental and construction legislations are not modernized to control the adverse impacts of construction activities in Bangladesh. A large volume of Construction and Demolition (C&D) waste and carbon are annually released from this sector. This research was undertaken to investigate the Green Supply Chain Management (GSCM) practices and its implications during the implementation in constructions. Three construction industries and three related material manufacturers were selected for case study, and thirty industries combing both categories were investigated through questionnaire survey to unravel current GSCM practices, and its challenges and effect on constructions. Results revealed that market (76.67%) and supplier (91.03%) pressures promoted GSCM practices in construction industries, additionally internal factors played significant role (74.44%), whereas 60% regulations as external pressure. As GSCM elements, green manufacturing (90.83%), green purchasing (85.83%), internal environmental management (82.5%), investment recovery (86.66), and eco-design (93.33%) respondents agreed to improve the construction industry to reduce C&D waste and carbon emission. About 89% and 79% respondents acknowledged the environmental and economic performances, respectively improved by GSCM practices. Furthermore, 70–90% respondents opined financial/technical/human application as key barriers in GSCM practices. Finally, the GSCM practices reduced C&D waste and carbon emissions; however, it was not maintained regularly and strictly.

**Keywords** Bangladesh · Construction industry · Supply chain · Sustainable · C&D waste

## Introduction

Globalization has manifold positive effects, especially economic development. However, it has some inconveniences in environmental and ecological perspectives. Therefore, organizations or industries should immediately react with the rapid-changing aggressive environment. Such alteration of the natural environment is caused by the fast and continued globalization [1–3]. Simply, globalization minimizes the cost to manufacture goods. Besides, worldwide locations can open new markets for selling goods and shorten the supply chain. As a result, the globalization led to rapid industrial expansion [4–6]. However, the unscientific *Supply Chain Management* (SCM) practices in industrial practices are responsible for environmental damage through wastes and pollutants discharge. A SCM is the process of managing the flow of goods to and from an industry, including every step involved in turning raw materials into final products and reaching them to the customers [7, 8].

An eco-friendly concept *Green Supply Chain* (GSC) emerged to mitigate adverse environmental impacts by

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adopting green practices in industries [9, 10]. GSC can be defined as the operational management system and maximization technique to reduce the adverse environmental effects along the life cycle of the product, from the raw material acquisition to the final product. The key GSC elements include green manufacturing, green purchasing, cooperation with customers, eco-design, and green information systems [11, 12]. However, *Green Supply Chain Management* (GSCM) can be obtained by counting environmental issues at the purchasing, product design and development, production, transportation, packaging, storage, disposal, and end of product life cycle management stages [13, 14]. According to Hervani et al. [15] and Srivastava [16], the practices of GSCM include resource management, green procurement, green production and assembly, green reverse logistics, and combination of SCM along with product life cycle management. GSCM mainly involved in practicing 3Rs (reducing wastage, reusing and recycling of resources). Green design, environmental management, green packaging, investment return, and green transport are also counted as element of GSCM [15, 17–19].

The current environmental challenges are major concerns of the associated authorities in building a sustainable environment. The GSCM processes emphasize on how green practices may ensure the sustainability of industrial environment and development through avoiding economic loss and environmental problems [20, 21]. Presently, the construction sector is rapidly boosting and contributing to environmental degradation as well. However, GSCM is still little acknowledged and less practiced in this sector, especially to reduce *Construction and Demolition* (C&D) debris and carbon emission [22–24]. The achievement of environmental sustainability through GSCM practices is a major concern in developing countries, especially in Bangladesh. The adoption of GSCM practices plays a crucial role in building a sustainable environment by minimizing C&D wastes and carbon emission [25–27].

Several research activities were globally conducted on implementation of GSCM practices in construction sector to observe their effects [13, 28–30]. Some of these studies developed framework for implementing GSCM practices in construction industries [23, 31]. Wibowo et al. [14] investigated the influential factors in implementing GSCM practices in construction sectors. Most of the related research focused on conceptual model of reverse supply chain practices for C&D waste [19, 32–35]. The EU published a waste management directive in 2008 to reach a 70% of C&D waste reduction by reusing, recycling, or recovering in 2020 [12]. Therefore, several studies investigated the application of GSCM practices in reduction of C&D wastes. They showed C&D waste generation rates 5.4 kg and 81% of them were landfilled in Tehran while about 44% landfilled in the United Kingdom. Thus, they demonstrated the demand of GSCM in construction sector [7, 11, 36]. Nguyen et al. [8] studied the influential factors in C&D waste minimization by GSCM practices. Wibowo et al. [37] showed the demand of GSCM strategy for the recycled materials in achieving sustainable construction. Huang et al. [34] showed 0.0259 tons $CO_2$ emission reduction by reducing transportation distance. Furthermore, some research demonstrated the need of purchasing waste-efficient materials in construction sector for sustainable development [38, 39].

The construction sector is booming in Bangladesh and contributing to the national economy. The generation of C&D waste and carbon emission from the construction activities is deteriorating the environment and ecosystem [20, 40, 41]. The environmental legislations are very poorly practiced or defectively implemented in the industrial sectors of Bangladesh, especially in construction industries. Currently, green practices, eco-friendly products, and green technologies are the vital concerns in the construction operations. The traditional construction practices may contribute to the environmental pollution by C&D wastes discharge and carbon emission [4, 42, 43]. However, the conventional pollution control approaches are adopted in construction firms instead of proactive solutions. Therefore, the current practices of SCM in construction sectors are liable for environmental degradation and economic loss. Therefore, it is urgent to adopt green practices in SCM to resolve the associated problems [27, 44, 45].

Most of the existing research on GSCM practices are conducted in developed countries. Therefore, there is still lack of relevant studies in developing countries like Bangladesh. The construction sectors of Bangladesh contribute about 10% to the national GDP [44, 46]. Similarly, the dearth of *Environmental Management Practices* (EMPs) contributes to environmental hazards, damage of natural ecosystem, climate change, less energy efficiency, insufficient waste management, and more carbon emission in Bangladesh. EMPs indicate a set of skills and strategies adopted by industries with the purpose of monitoring and managing the effect of their operations on the natural environment. These EMPs include actions, such as reducing, reusing, recycling, pollution prevention, and adopting advanced manufacturing technology [47–49]. Due to globalization and environmental concerns of the world, GSCM is the best tool to balance environmental and economic sustainability. It can improve the supply chain with respect to industrial and environmental sustainability through minimization of environmental footprints [22, 50].

Generally, the purpose of GSCM practices is to eliminate or minimize waste generation, energy consumption, carbon emissions, materials wastage, and use of chemical/hazardous materials along with the supply chain [15, 51, 52]. Recently, GSCM has emerged as a new approach for industries to achieve better profit, efficiency and market share objectives

by reducing the negative consequences [53]. It assists to break down the potential barriers and offers higher levels of services and reduced costs [34, 54]. Indirectly, it supports in the conservation of natural environment by increasing the efficiency of materials and energy used in the construction industry [47]. Therefore, GSCM practices in the construction industry are economically profitable, sustainable, and socially acceptable [55, 56].

Since the revolution of construction industry, they adopted some green practices in their supply chain. The conventional green initiatives are associated with many weaknesses, limitations, and problems [7, 40, 57]. Some of those initiatives are environmental consciousness, climate change, natural calamities, and ecological imbalance. Hence, the general supply chain is upgraded to GSC to diminish the adverse impacts and improve the environment with sustainable practices of construction industries [15, 31]. However, the contemporary literature of GSC practices in the construction industry is insufficient in Bangladesh. Therefore, the impact of construction activities on the environment is one of the major concerning issues. The construction industry produces a large amount of C&D waste and emits carbon per year. About 1.28 million tons C&D waste was generated during 2016–17 fiscal year [4, 58].

The construction industry is one of the largest and fastest growing industry in Bangladesh. However, there are several obstacles that are stopping it to flourish. According to Ofori [59], construction industry could benefit from the application of quality, waste and safety management. There are very few GSCM practices in construction industry due to poor implementation of legislation, insufficient knowledge on environmental sustainability, poor management, lack of coordination and cooperation, and lack of awareness among customer, manufacturer and supplier [4, 40, 44]. Hence, the challenges faced by this industry remained unresolved in Bangladesh. There is still no sufficient published information regarding GSCM practices, especially focusing C&D wastes and carbon emission. This research concentrated on the practices of GSCM in the construction sector to build sustainable construction with respect to the environment, emphasizing on minimizing C&D waste generation and carbon emission. This research identified the critical control points in the construction industry that underlie waste and carbon in the traditional supply chain in Bangladesh.

## Methodology

### Study area selection and research hypothesis

This study was mainly conducted in Chattogram City, Bangladesh that is located within 22°–14′ and 22°–24′–30″ *N* Latitude and between 91°–46′ and 91°–53′ *E* Longitude and on the bank of the Karnafully River [60]. Most of the surveyed construction companies are in Chattogram City. However, some industries are from other cities that would facilitate in presenting overview of the whole country.

The research hypothesis of this study is as follows:

H. Adoption of GSCM practices minimizes C&D waste generation and carbon emission in the construction industries of Bangladesh (see in Supporting Information).

### Secondary data collection

Secondary data support to get a comprehensive overview, and in some instances. It assists to interpret the data collected in the semi-structured questionnaires with the respondents. Besides, it supports in detailed content analysis. Such data are beneficial to give supplementary disputes or proofs in a broader perspective [61, 62]. Secondary data for this study include work process documents, sustainability docs, waste management record, supply chain records, handouts, report of the randomly selected construction companies, as well public documents, notification from *Real Estate and Housing Association of Bangladesh* (REHAB), Waste Concerns (NGO), and construction regulated bodies. However, for literature review, secondary data were collected from journals, university web portal, books, and Google Scholar.

### Sampling and primary data collection

This research was conducted using case study and survey methods of observations and semi-structured questionnaires to collect qualitative and quantitative data. For in-depth study, six case studies were conducted in the construction industries that were randomly selected. The primary data collection was done at ISO 14001-certified and non-certified construction companies. ISO 14001-certified companies were included because such companies took initiatives for green practices. Fifty (50) construction companies were selected using simple random sampling method in Chattogram City that are registered with REHAB, to collect wide varieties of data. The sample was collected from real estate developer and construction material manufacturer that included (i) 0–10 small companies, (ii) 0–30 medium companies, and (iii) 0–50 + large companies.

Semi-structured questionnaires were distributed to the Senior Manager/Manager/Civil engineer/Project manager/Site manager and Environmentalist of each company for data collection. Environmental data were collected from the published annual reports of the selected companies. The data was collected through (i) case study—semi-structure questionnaire, web-based documentary and observation; and (ii) survey—semi-structured questionnaire. Thirty (30) out of fifty (50) companies were responded. Six (6) case studies

from the construction firms and materials manufacturing industries used semi-structured interview questionnaire.

### Questionnaire design and survey

Semi-structured survey questionnaires and case study questions were used to collect primary data from the construction industry. The initial questionnaire was written in English; however, it was translated into Bengali to make understanding of the questions then distributed to 50 construction companies. The instruction was given to fill up the questionnaires by the respondents. The target respondents were briefed for this research, questionnaire, and ethics. The survey questionnaire has seven (7) sections—(a) Participant general information, (b) GSCM pressure, (c) GSCM practices elements, (d) GSCM performance, (e) GSCM application barriers, (f) C&D waste and reduction, and (g) Carbon emission. Here, the carbon emission data of the constructions industries were estimated based on the respondents' opinions. For quantitative data analysis, universal method of Likert five-point scale (e.g., 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree), and Likert five-scale point (1 = not at all, 2 = a little bit, 3 = to some degree, 4 = relatively significant, and 5 = significant) measurement was adopted. Based on literature reviews [9, 15, 63–68], observation and interview with industrial experts' questionnaires were developed [see Supporting Information (Table S1)].

After selection of the construction builders (30 nos) and relevant material manufacturing industries (20 nos) from the REHAB members list, the authors communicated with them through email and phone called and then shortly briefed about the research. Based on availability, the date was finalized, and questionnaires were sent to the respective respondent of the companies by post and physically. After filling up the questionnaires, they were collected physically. Before distribution and collection of questionnaires, the authors confirmed with participants on the interviews, observation, and site visit, and they had clear understanding.

### Data analysis

Primary data were recorded in MS Excel sheets from questionnaires, and then interpreted and prepared for statistical analysis (percentage and significance difference) through excel and SPSS software. Likert five (5)-point scale was used to categorize data into: strongly agree, agree, neutral, disagree and strongly disagree; and not at all, a little bit, to some degree, relatively significant and significant. The data were evaluated independent variables—GSCM elements: *Green Manufacturing* (GM), *Internal Environmental Management* (IEM), *Green Purchase* (GP), *Investment Recovery* (IR), and *Eco-design* (ED), and for dependent variables—GSCM pressure, GSCM performance, C&D waste and carbon emission to identify the relationship of the variables.

### Research ethics

Ethical considerations have been followed with regard to the university's ethical guidelines to mitigate any risks associated with this research. The proposed research was involved socio-economic and environmental factors. Permission was obtained from Bangladeshi construction companies, REHAB, and other related organizations to perform this research. Quantitative data were handled with care, and only original data from the published reports were collected to avoid the misuse of data. The publicly sensitive issues like cultural beliefs, social norms, etc. were carefully handled. The following ethical considerations were included:

All the participants were treated with care and respect. All kinds of biases were avoided. For secondary data collection, appropriate references were acknowledged. Confidentiality was strictly maintained with honesty and integrity. All the participants were informed early about the research title and usage of data, and participation was voluntary.

### Risk assessment

Some primary risks were identified including—there might be a challenge regarding the disclosure of information from companies about their practices. In managing this potential risk, the researcher was ensured that all verbal written information about the research indicates a possible researcher response to the disclosure. There was also the potential risk of not being able to meet the senior management of companies for a face-to-face data collection using questionnaires, as it was often very busy. To mitigate this risk, the researcher booked appointments with the identified senior management 2 months before the data collection and reconfirmed it through emails, and 1 month before the set date. If the researcher was unable to collect the expected data during the field visit, then more questionnaires were sent through post and email. Among the contracted construction companies, thirty (30) of them responded and assured the researcher that they would participate. A risk assessment was undertaken at each stage of the research and adequate risk control mechanisms were implemented where the need arose.

## Results and discussion

### Case studies of construction industry

Survey research covers many industries, so it cannot obtain details information where case study can conduct in-depth

study of individual industry. Therefore, six case studies were conducted to gain comprehensive insights into the causal relationship among factors obtained from the empirical studies. Three cases were real estate developers, namely *Development Design Consultants Limited* (DDCL), *Building Technology and Ideas Limited* (bti), and *Toma Construction and Company Limited* (TCCL); and three building materials manufacturers, *Bangladesh Steel Re-Rolling Mills Limited* (BSRM), *Shah Cement Industries Limited* (Shah Cement) and *Abdul Monem Auto Bricks Limited* (AM Auto Bricks). Here, real estate developers and construction materials manufacturers are investigated because both contribute to construction sector.

### GSCM practices in construction industries

***Development Design Consultants Limited (DDCL***) is an international engineering company. DDCL is one of the pioneer constructions companies that launched its journey in 1972. It has obtained several ISO certifications including ISO/IEC2000-1:2011, ISO27001:2013, and ISO 9001:2015. It provides the best engineering services with minimum environmental impacts. DDCL was graded as the 88th largest consulting firm by the Swedish Federation of Architects and Consulting Engineers. As one of the leading firms, it is highly diversified in expertise and sectoral specialization. It maintains highly committed and experienced professionals specialized in diverse disciplines. It has a well-structured environmental team along with other professional teams that can offer the best team for any development project. It has employed about 1300 professional staffs. DDCL is committed to conserve and protect natural environment, and ensure sustainable infra-structural development. Therefore, it is highly practicing GSCM to increase energy, materials and water efficiency including reduction of C&D wastes and carbon emission.

***Building Technology and Ideas Limited (bti)*** is a leading and pioneer real estate firm in Bangladesh. It launched its journey in the real estate sector in 1984 by developing residential apartments and subsequently expanded to commercial projects. It is the first and founding member of REHAB, formed on 12 December 1991. Currently, bti is working on developing international standard communities and commercial spaces, as well spreading its activities in international market. It has provided services to both government and private sectors. It has an organized professional team which consists of about 500–1200 employees. The annual turnover is USD150 million. bti has achieved ISO certification due to the recognition of its quality and continuous improvement. As the recognition of excellent works, it was awarded as 'AA3 and AA2 Credit Rating Enterprise.

***Toma Construction and Company Limited (TCCL***) is one of the leading construction conglomerates in Bangladesh. TCCL has 25 years of experience and developed into a professional construction team. The company has a diverse disciplines professional team who supported to reach TCCL present stage. It has around 6000 employees and an annual turnover of more than 117.34 million USD. To ensure a sustainable corporation, TCCL set out a code of ethics and all employees have pledged to adhere to it. It has own team to monitor and prevent any environmental and health accidents during operation of construction activities. It is an ISO9001:2015 quality management-certified company. The environment is the core element in its management strategy. It adopted several strategies to ensure sustainable construction and development including (i) comply with environmental laws and regulations, (ii) minimize pollutants discharge by introducing clean production processes and technologies, (iii) establish a resource recycling society and thus improve ecological sustainability, and (iv) take the lead in low-carbon green growth by reducing carbon emissions.

C&D waste generation and carbon emission from the studied constructions industries from the operational activities are shown in Fig. 1.

The GSCM practices are increased in construction sectors of Bangladesh. For example, *Green Manufacturing Practice* (GMP) includes all industrial practices utilizing raw materials with reasonably minimum adverse impact on the environment; however, with the efficient use of energy and water. It has several benefits, such as cost reduction, meets environmental requirements, and ameliorates corporate image. *Green Purchasing Practice* (GPP) and *Internal Environmental Management Practice* (IEMP) are not well-established in construction sectors. *Investment Recovery Practice* (IRP) enables an industry strategically to apply reverse logistics to derive greater value and sustainability from materials and products. IRP supports to recycle and resell additional raw materials, out of service equipment, demolished products and waste including process by-products [19, 28, 33]. *Eco-design (Green) Practice* (EDP) can effectively reduce most of the environmental impacts from the construction industry. The eco-design of construction materials minimizes the materials and energy consumption in infrastructure development. The main goal of EDP is to anticipate and minimize adverse impacts. It makes equipment and products more sustainable and competitive.

The comparative GSCM practices of DDCL, bti and TCCL is shown in Table 1.

### GSCM practices in construction materials manufacturers

Modern construction cannot be imagined without steel. ***Bangladesh Steel Re-rolling Mills Limited (BSRM)*** solely contributes about 45% of the national steel supply. BSRM is the largest construction steel manufacturer in Bangladesh. It

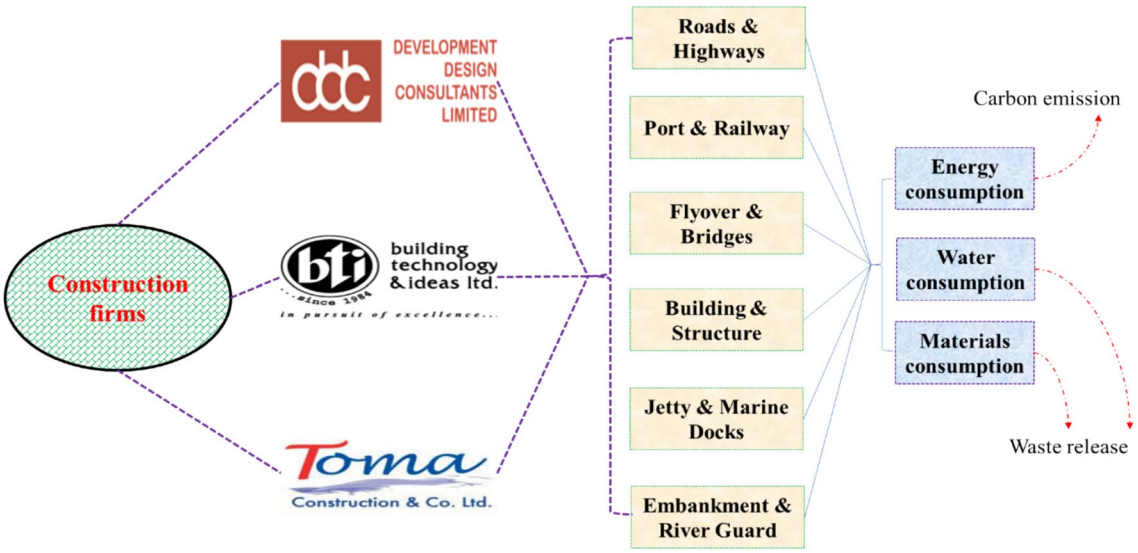


**Fig. 1** Overview of the major construction activities and their environmental emissions

started its journey with four manual rolling mills in 1952 that subsequently replaced with the state-of-the-art Italian built rolling mill in 1970. It has a subsidiary in Hong Kong named BSRM (Hong Kong) Limited. The main raw materials supply of BSRM is shipbreaking industries. It was the first Grade 500 steel and gradually promoted to BSRM Xtreme B500DWR. It produces steel for the construction conforming to ISO 6935-2:2015 and ISO 630-3:2007 that are the legal standards in Bangladesh. It was awarded as Number 1 (one) Steel Brand for 9 times in Bangladesh and achieved several awards from government and business associations. BSRM produced 1.6 million MT of steel in 2019 and earned US$1.56 billion revenue. It has more than 2800 employees including highly skilled professionals, technicians, workers and environmental experts. As leading steel industry, it is concerned about environmental problems associated with manufacturing activities. It has implemented GSCM practices to minimize waste and carbon emission.

Cement is one of the most essential construction materials. The local demand of cement is fulfilled by national private companies. ***Shah Cement Industries Limited (Shah Cement***) is a leading Bangladeshi cement manufacturing industry. Shah Cement is one of the top-selling cement brands in Bangladesh and contributed to 14% of the cement market in 2019. Abul Khair Group founded it in 2002 with an initial capacity of 5.2 million MT per year. It has its own power plant of 17-megawatt capacity to ensure uninterrupted power supply 24 h. The current capacity of Shah Cement is 10 million MT per year. It leads the state-of-the-art quality management system. The company received "Best Brand Award" from Kantar Millward Brown and Bangladesh Brand Forum in 2010, 2016, 2017, 2018 and 2020 in the building materials category. It is an internationally certified brand, and the customers can be assured about the cement quality of it.

***Abdul Monem Auto Bricks Limited (AM Auto Bricks***) was established in 2011. AM Auto Bricks is producing and delivering only bricks. It uses Automatic Machines that was made by China. Such machines are eco-friendly and cost-effective with high efficiency. A professional and experienced team is being engaged for the production and delivery of the bricks. Bricks are manufactured from the ancient time and still used hugely in modern construction in everywhere. However, the quality and structure/design of the bricks have improved from the ancient time. The modern bricks are eco-friendly and cost-effective because advanced technologies are used in manufacturing them. AM Auto Bricks use modern kilns to fire the molded bricks. Modern technologies and machines can refine bricks with minimum time and cost. It has expertise in the production of modern structural clay products. Eco-friendly processes are being maintained in AM Auto Bricks. So, it uses 30% less energy than traditional brick fields. In addition, it recycles heat generated in the kiln to dry green bricks and eliminates the emission of black smoke laden with $CO_2$ gas. Raw bricks are dried in a drying chamber with strictly controls temperature, airflow, and proper time. The best quality coal is used as fuel from Boropukuria and firing kiln ensures the uniform firing, preventing color variations, deformity, and shrinkage etc.

Waste and carbon emission from the studied construction materials manufacturers are presented in Fig. 2.

The construction sector demands many materials which are purchased from suppliers and construction materials manufacturers. Manufacturing industries implement GSCM practices. Amidst, GMP has several benefits, such as manufacturing cost reduction, fulfils environmental requirements

**Table 1** Comparative GSCM practices in major construction industries of Bangladesh

| GSCM practices | DDCL | bti | TCCL |
|---|---|---|---|
| GMP | Green packaging has positive impacts, | Supported relevant environmental regulations, | Gives priority on green packaging, |
| | Indirectly improved environmental quality, | Green packaging has positive impact on the construction, | Manufactures green concrete, |
| | Leads to recycling of construction waste and reuse of water, | Reused unused/access materials, | Adopted 3R strategy for sustainable manufacturing, |
| | Reduced hazardous materials use, | Increased recycling of wastes, | Efficient materials and energy use, |
| | Increased energy efficiency and reduced carbon emissions, | Reduced construction waste and carbon emission | Reduced pollution and carbon emissions, |
| | Reduced construction wastes | | Reduced construction wastes |
| GPP | Sent design specification, | Hires third-party for environmental audit of the suppliers, | Selects ISO certified supplier, |
| | Practices environmental audit system, | Gives priority on ISO14000 certified company if reasonable price, | Supplies own green design to suppliers, |
| | Select ISO14000 certified suppliers, | Does not practice GPP in reality | Has professional auditing team, |
| | Evaluates ecofriendly practices of second-tier supplier | | Evaluates second-tier supplier eco-friendly practice |
| IEMP | Committed to environmental management, | Senior managements are committed to environmental management, | Managers support to subordinate in environmental management, |
| | Provides training for creating environmental awareness and responsibility, | No training programmes, however, tries to create awareness, | Own environmental compliance and auditing programme, |
| | Complies with environmental regulations and standards of DoE, | Poorly complies with environmental regulations and policies, | Well-structured EMS developed by own professional team, |
| | Own environmental management system, | Weak environmental management and eco-levelling | Concerns about eco-labelling, |
| | Has ISO certification, | | Lowest carbon emission by using clean energy and technology |
| | Concerns for eco-levelling of products | | |
| IRP | Sells excess inventories to third party, | Sells excess capital equipment, | Sells excess materials to third party, |
| | Sells scrap and used materials, | Readily recyclable materials are sold to the third party | Scrap and used materials are sold, |
| | Sells excess materials and equipment | | No byproducts due to recycling |
| EDP | Designs products to reduce materials and energy consumption, | Weakly supports to environmental regulations, | Product design reduce materials and energy consumption including hazardous materials, |
| | Best utilization of 3R's technique, | Reduced energy consumption, | Products designs are supportive to implement 3Rs strategy, |
| | Increased energy efficiency, | Products and equipment design reduce use of hazardous materials, | Concerned about the efficient use of water, electricity, and gas |
| | Green transportation, | Energy efficient products and green transportation | |
| | Designs to reduce hazardous materials use | | |

**Table 1** (continued)

| GSCM practices | DDCL | bti | TCCL |
|---|---|---|---|
| Barriers to GSCM implementation | Internal barriers–High cost, lack of technology, poor commitment of top management and knowledge about the environmental impacts, lack of internal communication and human resources, and tailor-made guidance | Internal barriers–Lack of knowledge about environmental impacts, poor commitment by top management, lack of skilled professionals and information sharing | Internal barriers–Lack of environmental awareness, information and skilled human resources, and short-term planning over long time planning |
| | External barriers–Pressure of lower prices, lack of government support, and weak legal structure | External barriers–Lack of public awareness, weak legal government enforcement, and lack of regulatory bodies support | External barriers–Increasing construction materials costs, pressure of lower prices, lack of government support and regulation |

and customers' demands, and improves industrial market value. Globally environmental concern is growing up and hence GPP is getting popularity among them. Such industries highly contribute to environmental pollution and so have adopted IEMP. Environmental professionals are employed to ensure the environmental compliance (environmental laws, regulations, standards, and site permits to operate). Manufacturing industries are more responsible for air pollution and destruction of natural environment. So, the government regulatory bodies are enforcing such industries to comply with related legislations. IRP supports to recycle and resell additional/unused raw materials, out of service equipment, demolished products, and waste [32, 34, 35]. The adoption of EDP is increasing greatly in the manufacturing industries. The integration of environmental considerations into the equipment/product design and development that aims to improve performance throughout a product life cycle. In the competitive market, all manufacturing industries are emphasising on environmental conservation to upgrade their market value.

The comparative GSCM practices of BSRM, Shah Cement and AM Auto Bricks is shown in Table 2.

## Quantitative survey in construction industries

Survey research provides detailed data directly from the individual industries. This study surveyed different types of 30 construction industries (real estate developers and construction materials manufacturers) in Bangladesh. These industries are run by different authorities. The ownership type of the surveyed industries includes: 10% joint venture, 76.67% private, 6.67% state owned and 6.67% international. According to the size of industry and providing services, the employee size differed including: 16.67% micro (< 10), 26.67% small (11–50), 40% medium (51–250) and 16.67% large (> 250); similarly, 50% house building, 16.67% commercial building, 20% civil engineering, and 13.33% refurbishment and maintenance service providing industries. As construction materials, the surveyed industries purchased 16.67% virgin material, 36.67% recycled materials, and 46.67% mix materials from the suppliers (manufacturers). The quantitative findings of the study are presented and discussed below.

### Influential factors (pressures) in GSCM practices

The implementation of any policy or strategy faces challenges (pressures) in everywhere, especially in developing countries due to high illiteracy rate/lack of awareness and defective implementation of the relevant legislations [6, 69]. Bangladesh is one of the developing countries, so GSCM practices in the construction industries is derived by several external (market, supplier, regulations) and

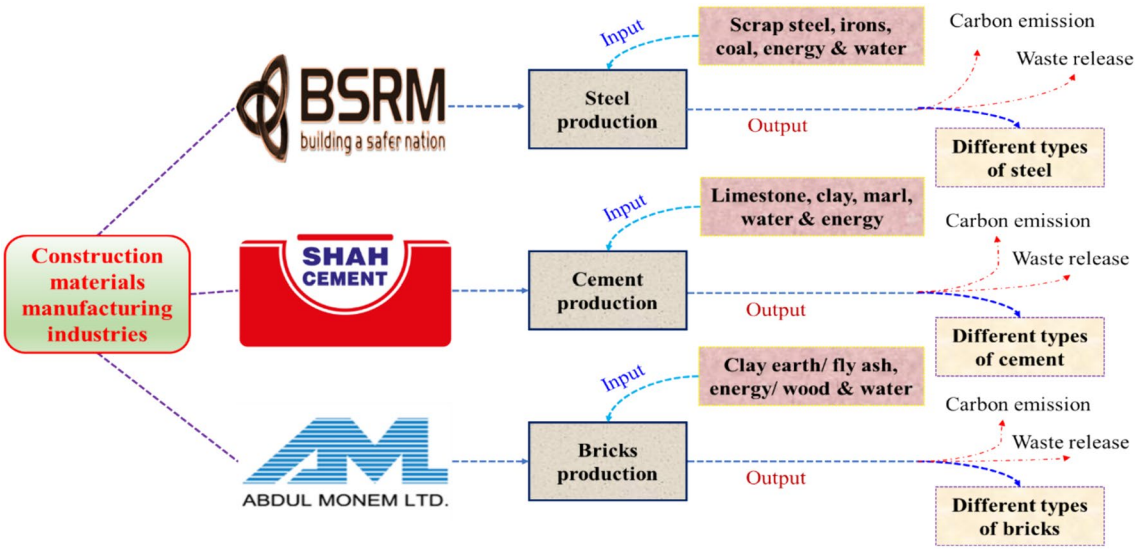


**Fig. 2** Operational activities of construction materials manufacturers and their environmental emissions

internal factors (environmental mission, multinational policies, disposal of hazardous materials, cost-effective eco-friendly goods and packages). The details of the studied influential factors are shown in Fig. 3 and Table S2 (Supporting Information). The consumer's environmental awareness and green image affected 90% and 63%, respectively as *market pressure* on GSCM practices. Statistical analysis showed $p$ value less than 0.05, denoting statistically significant. The consumer's environmental awareness and green image reduced C&D waste and carbon emission that agreed by Zhu et al. [70] and Nguyen et al. [8]. Consumer awareness encourages use of recycled C&D debris in construction activities that ultimately reduces waste generation. Besides, the reduction of new raw materials acquisition from natural sources declines carbon emission [14, 25, 37]. Similarly, eco-friendly goods pressure, supplier pressure introduces environmental partnership and eco-friendly package affected 93%, 90% and 90%, respectively as *supplier pressure* on GSCM practices. Analysis showed $p$ value $< 0.05$, so it was statistically significant. The eco-friendly goods, suppliers introduce environmental partnership and eco-friendly package pressured significantly reduced construction wastes and carbon emission that proved by previous studies [5, 41, 71]. According to respondents, regulations influence on GSCM practices was agreed 60% by central government, 53% by regional environmental, and 57% by international environmental regulations pressures. Analysis showed central government force on GSCM practices statistically significant; however, regional and international environmental regulations were not statistically significant. Hence, these two pressures cannot affect construction waste and carbon emission that is opposed by Chen and Sheu [72] and Jiang et al. [25]. The difference might be for the poor practice of related legislations in Bangladesh and other developing countries.

According to the findings of this study, the internal factors influenced more on GSCM practices than the external factors in construction industries. The surveyed respondents agreed that the internal factors influenced by 73% company environmental mission, 70% internal multinational policies, 80% potential liability for disposal of hazardous materials, 83% costly disposal of hazardous materials, 73% eco-friendly goods are cost-effective, and 67% eco-friendly packages on GSCM practices in construction industries. According to statistical analysis, $p$ value less than 0.05 that indicated statistically significant. All the studied internal factors in GSCM practices reduced C&D waste and carbon emission which supported by Hu and Hsu [53] and Guerra et al. [81]; however, the influence of external factors cannot be neglected at all.

### GSCM practices

The studied GSCM components include GM, GP, IEM, cooperation with customers, IR and ED (see Fig. 4). In case of GM, eight factors were investigated in this study. About 90.83% respondents agreed those factors affected on GSCM practices in construction industry. Statistical analysis showed $p$ value $< 0.05$, indicating statistically significant. Therefore, the studied GM factors contributed to C&D waste and carbon emission reduction by replacing traditional construction materials with organic-based materials. Similarly, 85.83% respondents agreed with the studied GP factors influenced on GSCM practices. Analysis showed $p$ value was less than 0.05 that meant statistically significant. The investigated GP factors minimized C&D waste and carbon

**Table 2** Comparative GSCM practices in major construction materials manufacturers

| GSCM practices | BSRM (steel) | Shah cement (cement) | AM auto (bricks) |
|---|---|---|---|
| GMP | Green packaging has brought a positive environmental impact, | Minimum environmental footprint, | Produces eco-friendly products, |
| | Operates water and waste treatment project, | Green packaging has positive effect, | Leading to recycling and reuse of waste and water, |
| | Implements 3Rs strategy, | Reduces energy consumption, | Reduced energy consumption and carbon emissions, |
| | Uses energy efficient technology, | Uses clean technology, | Improved environmental quality, |
| | Reduces energy consumption, | Less use of hazardous materials, | Waste reduction |
| | Reduced waste and carbon emission | Minimized waste and carbon emission | |
| GPP | Specific design is sent to suppliers, | Green designs for products, | Developed professional environmental audit team, |
| | Has own environmental audit team, | Increased cooperation with suppliers, | Hires third party to verify supplier, |
| | Gives priority on suppliers who acquire ISO 14000 certification, | ISO certified supplier, | Preferred choice is ISO 14000 certified company |
| | Second-tier supplier ecofriendly practice | Hires third party for conducting supplier's environmental audit | |
| IEMP | Senior management are committed, | Weak EMS and professional team, | No EMS and professional team, |
| | Employed environmental professionals, | Managers supports in environmental management, | Absence of managerial support, |
| | Creates environmental awareness, | Supports environmental regulations, | Poor environmental management, |
| | ISO 14000 certification, | Poor environmental management | Hardly supports environmental regulations |
| | Own EMS to minimize impacts | | |
| IRP | Initially inspects, selects, and sorts the scrap and then send to recycling plants, | Sells excess inventories to third party, | No extra materials to sell, |
| | Internally treats wastewater and reuse it, | Reusing of treated wastewater, | Reusing of treated wastewater, |
| | Operates a recycling plant that collects used waste steel and then recycle them | Recycling scrap and used materials, | Recycling waste, |
| | | Sells unused capital equipment | Sells additional equipment |
| EDP | Minimum use of hazardous materials, | Implements 3R strategy for materials, | Reduced energy and materials consumption, |
| | Implementation of 3Rs strategies, | Diverts waste from disposal, | Adopts 3R strategy, |
| | Uses highly efficient technology, | Sustainable production, | Avoids use of hazardous materials, |
| | Easy repair of equipment, | Reduced use of hazardous materials, | Supports environmental regulation, |
| | Complies with environmental legislations, | Uses energy efficient technology | Easily repairs equipment |
| | Practices eco-levelling | | |

**Table 2** (continued)

| GSCM practices | BSRM (steel) | Shah cement (cement) | AM auto (bricks) |
|---|---|---|---|
| Barriers to GSCM implementation | Internal barriers–Lack of knowledge about environmental impacts, no information sharing between customers/suppliers, high operation costs, lack of skilled human resources and top-level management commitment, poor internal communication, and inappropriate organization structure | Internal barriers–Lack of environmental knowledge, no information sharing between customers/suppliers, high operation cost, lack of skilled human resources and internal communication, and inappropriate organization structure, | Internal barriers–Lack of environmental knowledge, skilled human resources and top-level management commitment, and inappropriate organization structure |
| | External barriers–Low price pressure, lack of government support, and government legal enforcement | External barriers–Low price pressure, high raw materials costs, and lack of government support | External barriers–Lack of raw materials supply, low price pressure from customers, and lack of government support |

emission by purchasing energy saving and waste-efficient materials and equipment [38, 39]. About 82.5% respondents positively answered the studied IEM factors affected on GSCM practices, whereas 17.5% respondents disagreed about the impact of the support of environmental regulations. Statistical analysis showed significant differences between agreed and disagreed respondents about the effect of IEM on GSCM practices. Similarly, 73–90% respondents agreed that cooperation with customers for including environmental requirements influenced on GSCM practices in construction industry. Analysis showed statistically significant in terms of IEM and customer's cooperation's effect on GSCM practices that supported by previous studies [47, 73, 74]. In case of IR, 86.66% respondents agreed that the investigated factors affected GSCM practices. Statistical analysis showed $p$ value $< 0.05$ which indicated statistically significant. So, the investigated IR factors reduced C&D waste and carbon emission. Similarly, previous research demonstrated reduction in waste and carbon emission from construction activities by recycling (saving energy and reducing carbon release) and reusing (diverting new raw materials acquisition) C&D debris [19, 28, 32–35]. About 93.33% respondents opined the studied ED factors impacted on GSCM practices. Analysis showed statistical significance and so alternate hypothesis was accepted. The studied ED factors significantly reduced C&D waste and carbon emission. The ED practice also reduced C&D waste and carbon emission in both developed and developing countries according to previous studies [46, 75, 76].

### GSCM performances

The GSCM performance is studied in environmental, economic, and operational perspective in construction industries of Bangladesh [Fig. 5 and Table S3 (Supporting Information)]. In case of environmental performances, 88.66% respondents acknowledged that GSCM practices promoted the studied environmental performance factors. Statistical analysis showed that there was significant difference between respondents agreed and disagreed about the effect of the investigated environmental performance factors on GSCM practices. The improvement of environmental performance significantly reduced C&D waste and carbon emission by adopting 3R's practices. In case of economic performance analysis, 78.66% respondents agreed GSCM practices improved positives economic factors while only 23.35% respondents agreed about negative economic factors increased. It was statistically significant that the investigated positive economic factors greatly influenced GSCM practices and minimized C&D wastes and carbon emission by reusing recycled wastes. About 74.89% respondents agreed GSCM practices in construction industries promoted operational performances according to the studied factors. The

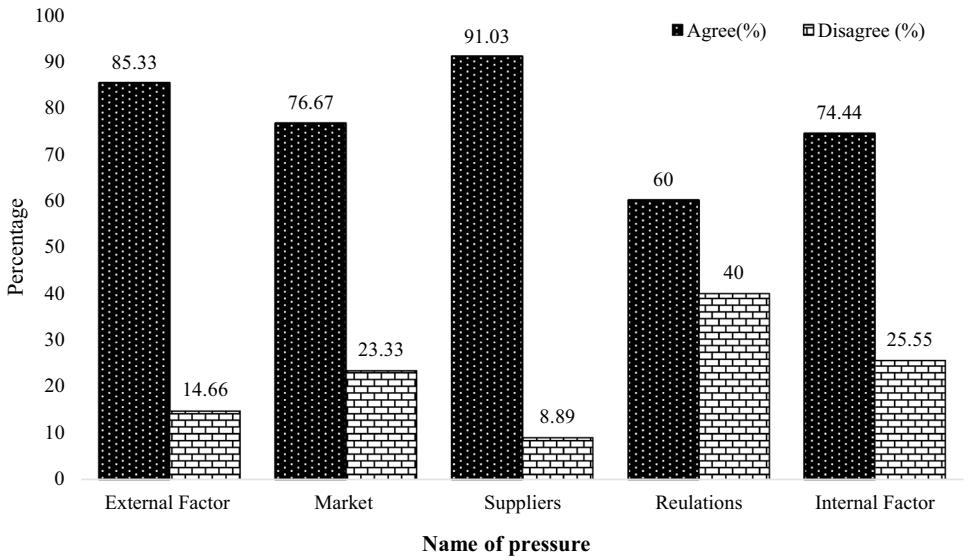


**Fig. 3** Overview of GSCM pressure in the construction industry of Bangladesh

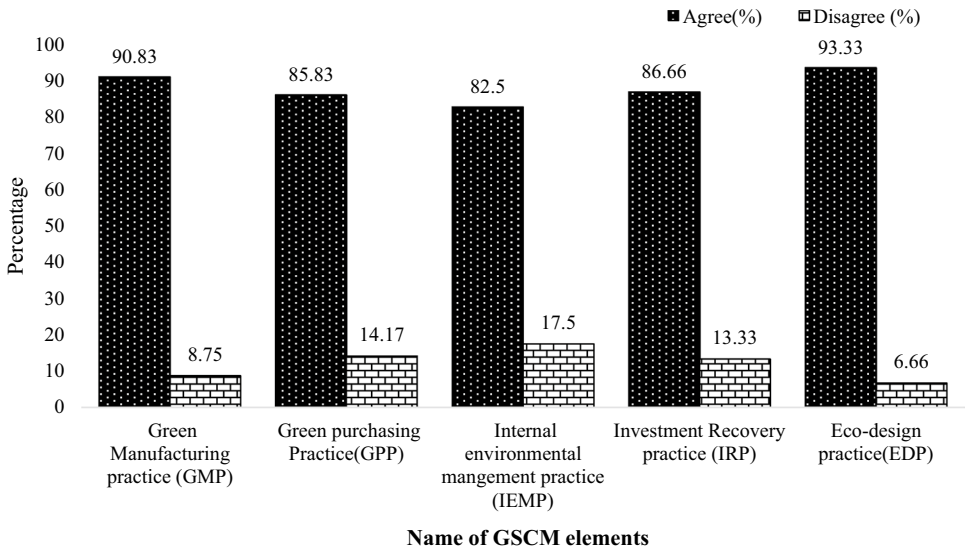


**Fig. 4** Overview of the practiced GSCM elements in construction industries

influence of studied factors on GSCM practices, as well C&D waste and carbon emission was statistically significant, agreed by Vachon and Klassen [10] and Zhu et al. [66]. Several reports showed that the improvement of GSCM performances in construction industries eliminated C&D waste generation and carbon emission using recycled wastes and minimizing the retrieving rates of virgin raw materials [9, 15, 29, 31, 34].

### GSCM application barriers

This research investigated more than 18 barriers that influenced on GSCM practices in construction industries (see Fig. 6). All these barriers directly or indirectly influenced on GSCM practices and subsequently in C&D wastes and carbon emission. The findings showed that 70–90% respondents agreed about the studied factors affected on GSCM practices, whereas the highest affected barrier was found as financial/technical/human application barrier and the lowest affected barriers were inappropriate organization structure and knowledge about the environmental impacts of the company. The statistical analysis showed $p$ value $< 0.05$ that meant statistically significant. The investigated GSCM application barriers significantly affected C&D waste reduction and carbon emission agreed by previous studies [49, 76, 77]. Several researches demonstrated that the main barriers in implementing GSCM practices were lack of sufficient knowledge, skilled technical persons, and financial support in developing countries [2, 8, 13, 14].

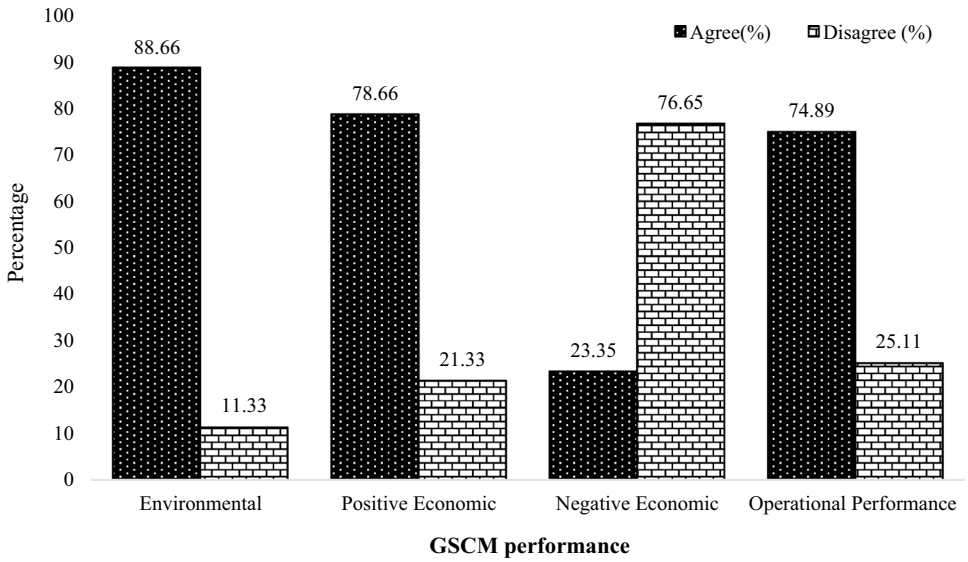


**Fig. 5** Overview of GSCM performance in the construction industry

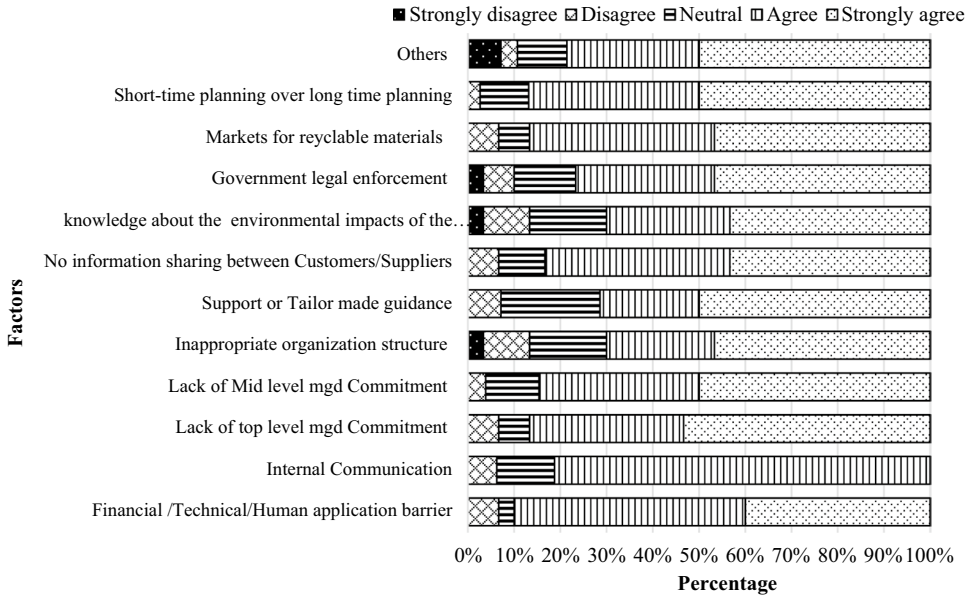


**Fig. 6** Percentage of different barriers impact on GSCM practices in construction industries

## Construction waste reduction

The C&D waste generated in Bangladesh mainly classified as solid waste, liquid waste, and volatile waste. In further classification, solid waste included concrete, bricks, timber, plastic, glass, metals, cardboard/papers, and other wastes (see Table 3). According to the respondents, statistically significant ($p$ value $< 0.05$) amount of C&D waste was generated including concrete, bricks, timber, plastic, metals, and cardboard/papers that supported by previous studies [36, 37, 78–80]. However, the generation of glass and other wastes as C&D waste was statistically insignificant that was disagreed by previous studies, which might pose problems in investigation methodologies or differences in economic status of the studied area. The liquid and volatile waste generation was not statistically important in construction industries that agreed with previous studies [23, 34, 81, 82].

Recently, the volume of C&D waste is considerably declining in Bangladesh due to the adopted strategies by the construction industries. These strategies included implementation of 3R's technique (enforced by government regulating authorities), modern eco-friendly design (i.e., demand less materials) and diversion of C&D wastes from being landfilled through resources recovery. Thus, the reduction of C&D waste contributed to the overall waste management. Most of the wastes generated from different sources are generally mixed up with municipal solid wastes and then disposed. Therefore, the diversion of C&D wastes from disposal

**Table 3** Types of wastes generated in the studied construction industries

| Category | Type of waste | Agreed respondents | | | | |
|---|---|---|---|---|---|---|
| | | Not at all | A little bit | To some degree | Relatively significant | Significant |
| Solid waste | Concrete | 0 | 2 | 5 | 9 | 14 |
| | Bricks | 0 | 3 | 4 | 8 | 15 |
| | Timber | 0 | 2 | 7 | 9 | 12 |
| | Plastic | 0 | 3 | 4 | 9 | 14 |
| | Glass | 1 | 4 | 9 | 10 | 6 |
| | Metals | 2 | 6 | 11 | 7 | 4 |
| | Cardboard/Papers | 0 | 3 | 7 | 9 | 11 |
| | Others waste | 3 | 4 | 8 | 6 | 9 |
| Liquid waste | | 1 | 7 | 8 | 10 | 4 |
| Volatile waste | | – | 6 | 9 | 8 | 7 |

minimizes waste disposal cost. Furthermore, it reduces air and water pollution by avoiding the release of pollutants along with reduced waste deposit to land [see Fig. 7 and Table S4 (Supporting Information)]. Among the four studied waste management factors (reduction or modification of waste management plan, increase recycling to reduce waste, life cycle assessment and reduction or modification of solid waste), only three factors statistically significantly influenced in waste reduction. However, increase recycling to reduce waste was not statistically significant in case of C&D waste reduction. Almost similar results were shown by previous studies [28, 83, 84]. In contrast, some previous studies opposed with the findings of this study [36, 49, 85] which might be for experimental design or unwillingness to share accurate data by the respondents. Additionally, in case of air pollution 66.67%, water pollution 53.33%, waste deposit land 55.17% and through waste management 62.5% agreed by the respondents to minimize waste in construction industry through GSCM practices.

### Sustainability and economic

Sustainability and economic growth are very important in any industrial sector. These help construction industries towards net zero carbon and waste emission which subsequently, improve the environmental quality and market value of the industry. About 79.33% respondents agreed while 20% respondents disagreed that the sustainability factors (i.e., contribute to environmental protection, reduction of solid waste, reduction of environmental risks, reduction of carbon and conserve natural resources) improved after the implementation of GSCM practices in construction industries (see Fig. 8). The highest sustainability effect was on conserving natural resources. The investigated sustainability

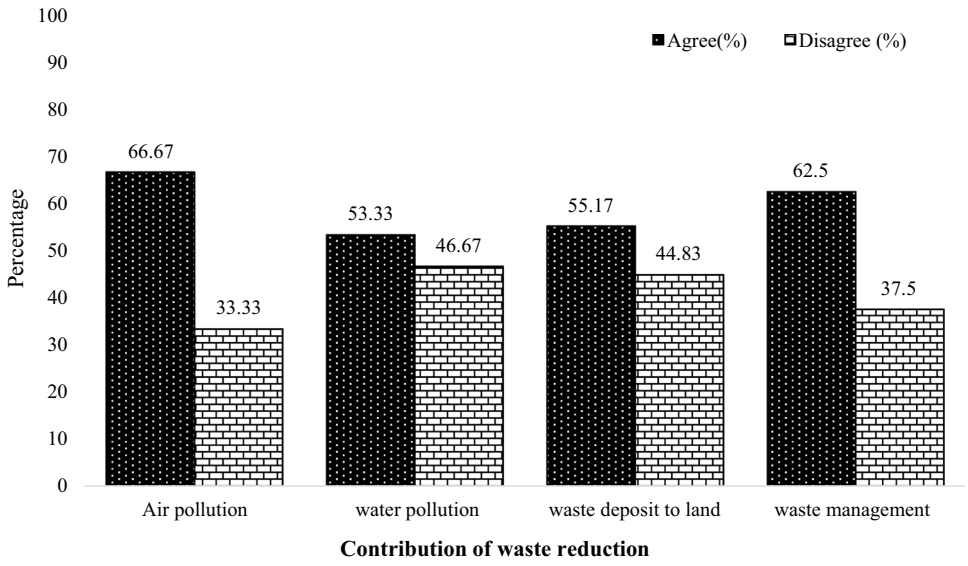


**Fig. 7** GSCM practices help to waste reduction in the construction industry

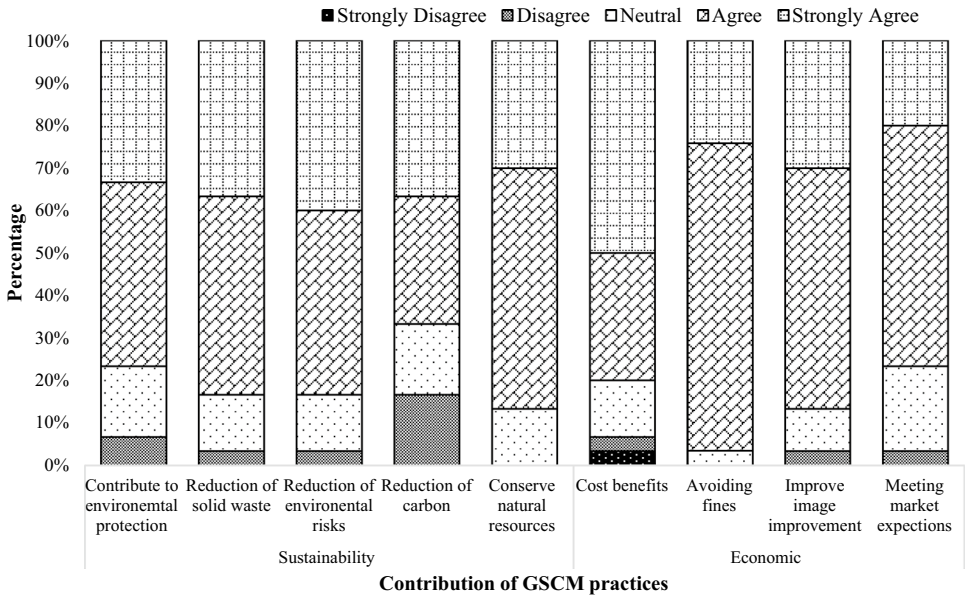


**Fig. 8** Sustainability and economic analysis of GSCM practices in construction industry

factors significantly reduced C&D waste and carbon emission including environmental risks.

Similarly, 84.97% respondents agreed while 15.02% respondents disagreed that the economic factors (cost benefits, avoiding fines, improve image value and meeting market expectations) improved according to the respondents after GSCM practices in construction industry (see Fig. 8). The main economic benefits were avoiding fines for mismanagement or violating environmental legislations. These factors progress benefited economically as well improved brand image and fulfilled the customer's requirements.

## Conclusion

Construction industries are continuously polluting environment through waste release and carbon emission. However, such impacts can be minimized through the effective implementation of GSCM practices. The GSCM practices are still partially implemented due to the absence of required supports in Bangladesh. Therefore, they cannot fulfil the environmental objectives in construction industries. The executive team is committed to support environmental compliance and auditing programs; in reality, it is not properly noticed. Furthermore, the suppliers ISO14000 certification is not always mandatory. The available IR practices cannot bring significant benefits in terms of 3R's implementation. The eco-design is growing up to reduce C&D waste and carbon emission; however, still it is not perfectly practicing. The main barriers in GSCM practices include lack of government support and alternative technology, slow rate of return, high cost, and lack of killed human resources. Environmental performance—reduced waste, water consumption, hazardous waste, and environmental accidents—subsequently brought positive economic benefits. However, the negative economic benefits were not significant. The operational performance decreased inventory cost and increased products quality.

The application of GSCM practices minimized considerable amount of C&D waste and carbon emission from construction sectors according to the respondents experiences and authors opinions that subsequently eliminated air and water pollution, and landfill demand. According to survey findings, GSCM practices demonstrated positive environmental effects in construction industries. Therefore, the concerning authorities should adopt the required strategies to compel such industries to implement GSCM practices fully in their construction operations. In addition, they can provide technical and financial support to those industries which are attempting to include GSCM practices in their industrial policy and vision. However, there is limitation in sample size and data accuracy in this study due to the limited access to industries and unwillingness to share the actual data (it might be for hiding their own faults that violating government regulations and considering sharing data is wastage of time). Therefore, it is recommended to conduct such research in future that may explore the real challenges in implementing GSCM practices along with forward solutions.

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**Data availability** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to their containing information that could compromise the privacy of research participants.

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