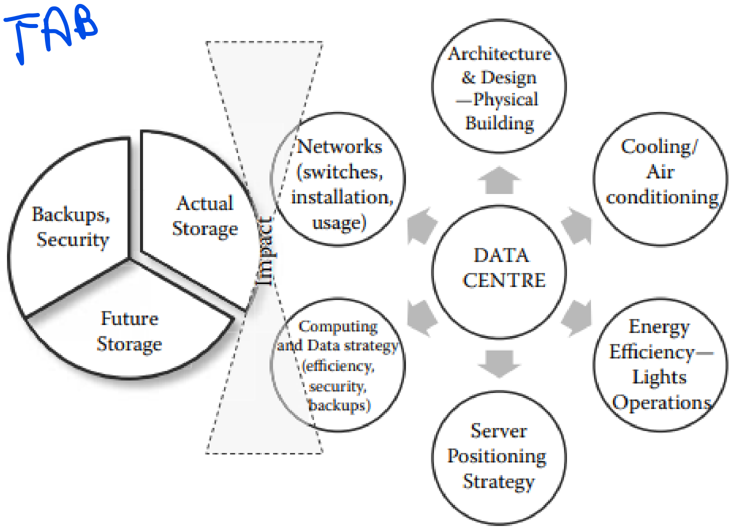
1.What is the impact of the data center aspect of green IT strategies on carbon reduction?

The demand for data center capacity worldwide has been on the rise. This has also lead to a steady increase in carbon emissions. For example, by year 2020, the world will be using 122 million servers up from 18 million or so in 2008–2009 (IBM, 2008; Chuba, 2008). In addition to the annual increase of approximately 9% in server numbers, one can also anticipate a change in the type of these server machines. This is so because servers will not only handle greater volume but will also require greater processing.

As mentioned earlier, data centers form the major chunk in the overall Green IT hardware assets of an organization. Ā ey house a suit of large computers and associated networks of the organization, forming the "heart" of most businesses. Ā ey hold the data and information residing in the organization's data warehouses that are residing within these data servers, which in turn, are placed in the data centers. Data servers, in practical terms, can be seen as powerful computers that have the capacity to store as well as process vast amount of multiformatted data. Ā erefore, these data centers are, understandably, the major power guzzler for an organization. Ā is growth in demand for vast amount of data storage coupled with corresponding demand for increasingly fast processing resulting in carbon emissions. As Cloud computing makes rapid strides, data, in its myriad multimedia format will have to be stored and instantly made available upon request. Apart from the business users who need to store data in perpetuity—at times justifiably as it enables them to comply with legislations (such as the Sarbanes–Oxley accounting data legislation)—consumers of these data also range from school students doing their projects, doctors exchanging new techniques in treating patients, and social users loading and watching video clips on YouTube. Ā e demand of storing and processing of data is unabating. Ā erefore, businesses that particularly deal with contents (e.g., entertainment, news) have to improve the energy efficiency of their data centers through innovative strategies in data management. Ā is means finding efficiency even in complexity. Ā e data management solutions need to be agile so as to cater to rapidly changing data needs. Dynamic and agile data management implies ability to modify, update, backup, and mirror data even as the organizational needs of the data keep changing. Innovation, together with disciplined operational management of the data center is required. Costs and carbon emissions are also closely tied together in case of data centers. Green data centers include the architecture, design, construction, operation, and decommissioning of buildings specifically used for housing servers. Green data centers also include the architecture, design, development, production, procurement, installation, operation, and disposal of the data server machines and their associated paraphernalia—such as monitors, printers, storage devices, and networking and communications systems.

FAB



as well as industrial metrics relating to carbon emissions from buildings, racks of servers, and individual machines. Specific areas for Green IT with respect to data centers shown in Figure 4.5 are discussed as follows:

- *Data center design, layout, and location*—Physical building in which the data center resides. Ā is can be one building, or multiple buildings that house the machines but are themselves spread across geographical regions. Architecture and design of the building (physical shape, naturally cooling and ventilation, natural light, ease of access etc.), geographical region (e.g., locating a data center in Iceland), and the material used in construction of the building (Terracotta for roofing; painting the roofs white) are all valid considerations here. Ā e size and design of rooms in which servers are housed and also the location of the server rooms within the data center can play a role in carbon reduction. For example, if the room to house the server exactly fits the server size, cooling effect will be maximized. Ā ese purpose-built data center buildings are a major influence in an organization's green endeavor.
- *Cooling, air conditioning, power source and power consumption*. Ā is includes the cooling strategies of the servers; and the air conditioning relating to the actual building. CRAC, as a specialist discipline, plays a role here. Also wherever choice permits, this also includes use of green energy sources (such as wind or solar). Furthermore, the impact of the physical location of the rooms to be cooled, that are housing the servers.
- *Power management—lights and operational aspect*. Number of people working, opening and closing of doors. Ā is would include procurement and installation of green products (such as LED light bulbs) and use of green services. Ā e source of renewable energy mentioned in the previous factor also plays a role in power management.
- *Servers—their numbers, their positioning and corresponding energy-efficient computing*—Physical location of the racks, their positioning (hot isle/cold isle). Architecture and the physical rooms in which they are placed. Design of each server—water cooled, air cooled, and other efficiencies are also to be considered.
- *Data strategy—including security and backup*. Virtualization within each server, and combined virtualization. Organization of a cluster of servers—private cloud. Space storage and usage strategy. Virtualization aims to pool resources together to deliver data center services by pooling resources that may be otherwise underutilized. Adopting virtualization strategies and creating ground-up virtualization architectures will enable data center energy efficiencies. Virtualization software such as VMware and SWsoft, coupled with consolidation analysis software such as CiRBA, can enable people to maximize server production while providing the same reliability and functionality (Ryan, 2008). Ā ere are new server management tools for better control and visibility into the capacity usage (Yi and Āomas, 2007).
- *Networks and communications equipment*, made up of land-based as well as wireless communications such as switchgears, routers, and modems. Ā e numbers and capacities of these equipments in the data center contribute to its carbon footprint.

Data centers are a critical component of green IT strategies, as they consume a significant amount of energy and contribute to carbon emissions. The impact of data center aspects of green IT strategies on carbon reduction can be significant, as follows:

- Data center design, layout, and location: The design and layout of data centers can have a significant impact on energy consumption and carbon emissions. Efficient designs, such as using hot and cold aisle containment, can reduce cooling requirements and energy consumption. Choosing the location of the data center can also impact the carbon footprint, as locations with lower energy costs and access to renewable energy can reduce emissions.
- Cooling, air conditioning, power source, and power consumption: Data centers require cooling and air conditioning systems to maintain the ideal operating temperature. Using efficient cooling systems, such as free cooling, and optimizing the temperature and humidity levels can reduce energy consumption and carbon emissions. Using renewable energy sources, such as solar and wind power, can also reduce emissions.
- Power management: Implementing power management strategies, such as using virtualization, consolidation, and power capping, can optimize power usage and reduce energy consumption. This can significantly reduce the carbon footprint of data centers.
- Servers: Choosing energy-efficient servers, such as those with higher power efficiency ratings and those designed for virtualization, can reduce energy consumption and carbon emissions. Using server virtualization can also increase server utilization and reduce the number of physical servers required.
- Data strategy: Implementing data management strategies, such as data deduplication, compression, and archiving, can reduce storage requirements and energy consumption. This can lead to a significant reduction in carbon emissions.
- Networks and communications equipment: Choosing energy-efficient networking equipment and optimizing network configuration can reduce energy consumption and carbon emissions. Using teleconferencing and video conferencing tools can also reduce the need for travel, leading to lower emissions.

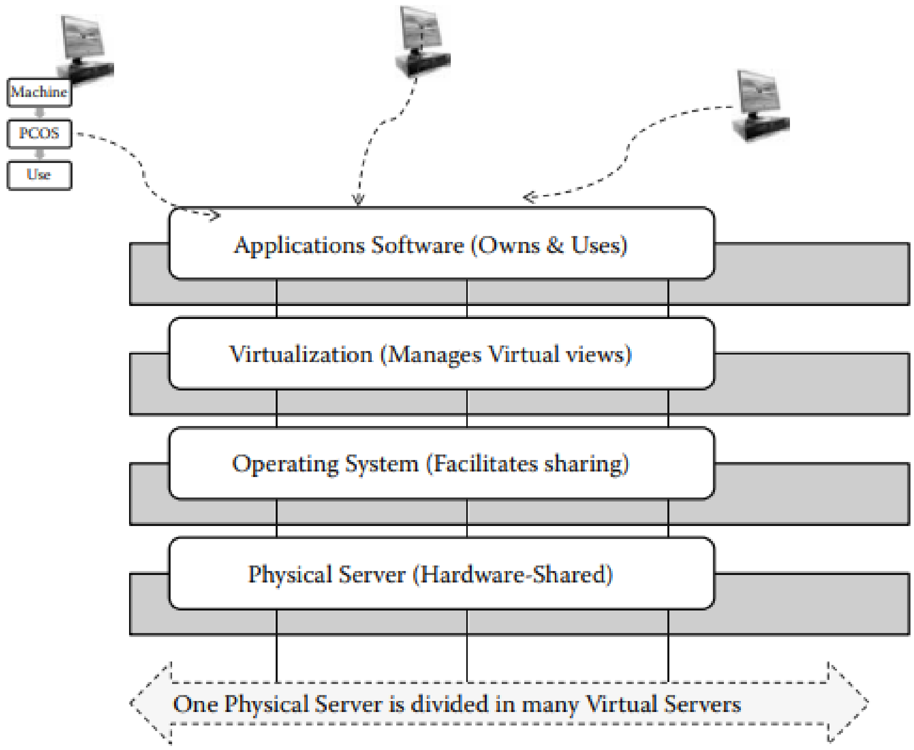
2.What is virtualization? what are the advantages and risks associated with virtualization?

Data Servers Virtualization

Of the many approaches and options discussed in terms of efficient data server management, virtualization can be considered as the most important one. Data server virtualization, as a key strategy, includes creation of many virtual servers from one physical server. Virtualization has been popular as an efficient hardware resource utilization; however, it also has significant impact on reducing carbon emissions.

Ā rough virtualization, data centers can consolidate their physical server infrastructure as multiple virtual servers are hosted on lesser number of servers. Ā is result in reduced power consumption, reduced number of servers, and also reduced

demand on the data center infrastructure. For example, virtualization reduces the demand on the data center floor space, which, in turn, reduces building size, number of people required to run the center, and reduced number of support tasks. Virtualization has to be supported by the operating system that would separate the underlying hardware from corresponding application software. Ā is is shown in Figure 4.7. As also shown in Figure 4.7, virtualization software is mainly focused on creating multiple views of the same underlying hardware and operating system. Sometimes, the operating system is itself equipped with virtualization capabilities. Ā ere are various ways and at various levels at which virtualization can be implemented. Ā es e include presentation virtualization (wherein users get a feel for owning the presentation of an application, whereas it is actually shared), application virtualization (enables multiple users to use the same application), desktop virtualization (applies the virtualization techniques of the servers at a local, desktop level), storage virtualization (applied to databases), and network virtualization (relates to the communications and networking equipments of the data center). Ā es e various



Virtualization is the process of creating a virtual version of something, such as an operating system, server, storage device, or network resource, using software. The virtualization software creates a virtual environment that is separate from the underlying physical hardware, allowing multiple operating systems or applications to run on a single physical machine.

Virtualization can contribute to green computing in the following ways:

Energy efficiency: By consolidating multiple physical servers into a single virtualized server, energy consumption can be reduced. This can lead to lower energy bills, as well as a smaller carbon footprint.
Resource optimization: Virtualization enables better utilization of resources such as CPU, memory, and storage. This results in fewer resources being wasted, and a more efficient use of hardware.
Reduced hardware needs: By running multiple virtual machines on a single physical machine, the need for additional hardware can be reduced. This can lead to lower costs and less waste.
Improved lifecycle management: Virtualization can improve the management of IT resources throughout their lifecycle, from acquisition to disposal. This can reduce waste and ensure that resources are used efficiently.
Risks associated with virtualization include:

Performance issues: Virtualization introduces overhead, which can impact the performance of applications running on virtual machines.

Complexity: Virtualization can introduce additional complexity, which can make it more difficult to manage and maintain IT resources.
Security concerns: Virtualization can introduce new security risks, as multiple virtual machines are running on a single physical machine. This can make it easier for attackers to exploit vulnerabilities and gain access to sensitive data.

3.List with examples the factors influencing green data centers. How can cloud computing help reduce carbon emissions?

Factors influencing green data centers include:

Energy efficiency: Efficient use of energy is a key factor in reducing the carbon footprint of data centers. Factors such as power utilization, cooling, and server efficiency all play a role.

Renewable energy: Using renewable energy sources, such as solar or wind power, can significantly reduce the carbon emissions of data centers.

Data center location: Locating data centers in areas with access to renewable energy sources, cool climates, and lower energy costs can help to reduce carbon emissions.

Virtualization: Virtualization enables more efficient use of hardware resources, reducing the need for physical servers and energy consumption.

Cloud computing: Moving workloads to the cloud can reduce the energy consumption and carbon emissions of data centers by allowing for more efficient use of resources and reducing the need for physical infrastructure.

Data center design: Data center design plays a critical role in reducing the carbon footprint. Factors such as the use of efficient cooling systems, hot and cold aisle containment, and efficient server design can all help to reduce energy consumption.

Cloud computing can help reduce carbon emissions by:

Improved resource utilization: Cloud computing enables more efficient use of resources by allowing for dynamic allocation of computing resources as needed. This can reduce the need for physical infrastructure and reduce energy consumption.

Energy efficiency: Cloud providers can leverage advanced energy management techniques, such as server virtualization, power management, and dynamic provisioning, to optimize energy usage.

Use of renewable energy: Many cloud providers are committed to using renewable energy sources, such as wind and solar power, to power their data centers. This can significantly reduce carbon emissions.

Reduced travel: Cloud computing tools, such as video conferencing and collaboration software, can reduce the need for travel, leading to lower emissions.

Cloud Computing and Data Centers

The offerings of Cloud computing have a role to play in carbon reduction. However, it has to be a highly balanced act. The cloud can take the responsibility of carbon emissions of a business outside its boundaries. But that is not necessarily an overall reduction in carbon emissions by the IT industry. A cloud, as a offering of computing services on the Internet, provides "a new consumption and delivery model for information technology (IT)" (Mell and Grance, 2009). Consolidation and optimization of services on a Cloud, resulting from on-demand self service, ubiquitous network access, location independent resource pooling, rapid elasticity and provisioning, and pay-per-use—all go toward reducing carbon footprint of the IT industry.

Cloud computing (Murugesan, 2011) provides substantial opportunities for organizations to consolidate their hardware and corresponding data space requirements. Cloud computing offers the potential for economies of scale that go beyond a single data center and a single enterprise. Ā is is so because with Cloud computing there is opportunity to not only consolidate the costs of services but also shift the carbon generation to a relatively centralized place where it can be better controlled and optimized. Alford and Morton (2009) estimated that the use of Cloud computing costs an organization two-thirds less than running the same workload on a private nonvirtualized data center. Ā e concept of Cloud computing is also applied within the organizational boundaries, especially for large, multinational organizations. Ā is results in consolidation of applications, data warehouses, and hardware within the organization, resulting in what is called a private cloud (discussed by Velte et al., 2009). Ā e "software as a service" (SaaS) business model emanating from Cloud computing allows companies

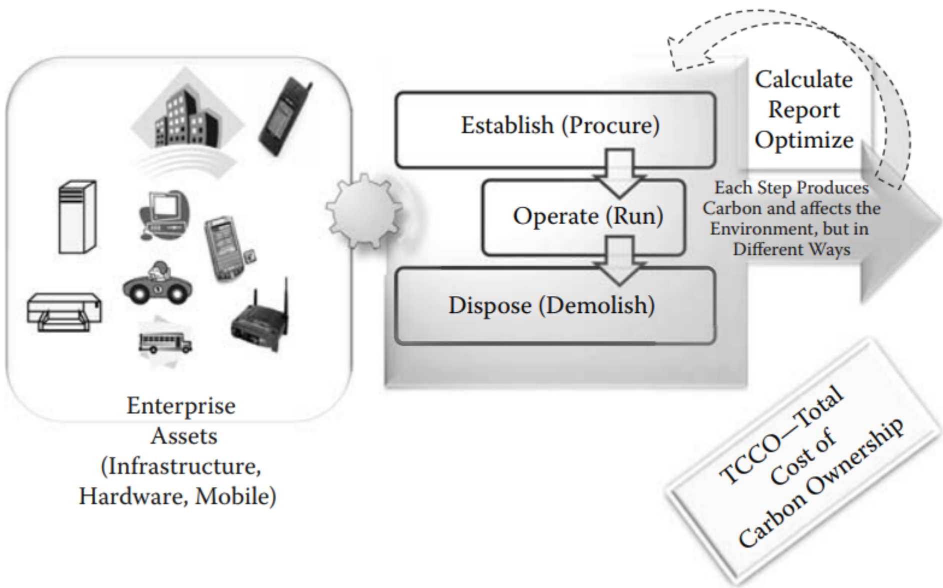
to access key enterprise applications such as customer relationship management (CRM) and supply chain management (SCM) through the Internet. As a result, the cloud obviates the need to host these applications in a proprietary data center. Ā e opportunities to reduce carbon emissions increase with consolidation of both hardware and software applications. Furthermore, the payment models for SaaS-based applications is usually based on its usage—akin to the typical monthly bill received for utilities such as gas or electricity. Ā e typical data center planning that makes provision for even-

4.Describe the various assets of an organization from their carbon generation perspective .

Type of Assets	*Impact on Environment*
Buildings and Facilities (e.g., offices, meeting rooms, training centers, social rooms, sports facilities)	Long-term impact as major environmental considerations should be during architecture and construction. Purpose of buildings, people movements, geographical locations (weather), and durability of the building impact their overall carbon contribution. Examples of one-off decision making in design include the materials used in the construction, the extent to which the building is facing the sun, the wind directions, and the way in which these natural light and natural cooling are put together to reduce energy consumption.
Data Center (as separate, dedicated buildings to house servers)	This is a special purpose building to house data servers. In addition to the standard building considerations, the ratio between power usage by the servers versus the rest of the power is a popular environmental consideration. CRAC (Computer Room Air Conditioning) is a discipline in its own right that separates the cooling of the servers from the air conditioning required in rest of the building. Thus, building technologies together with data server technologies are put to use here to reduce carbon.
Devices (e.g., laptop, mobiles)	Design, development, procurement, operation, and usage of devices is considered here. Example of this includes low-power consuming design for laptops and mobile devices, efficient batteries for them, carbon-conscious electronic chip design, biodegradability of materials used, and so on. Apart from the operational carbon generated by these devices, their disposal itself is an important issue.
Vehicles (e.g., cars, trucks, corporate vans, and buses)	Direct fuel emissions, pollution level of the type of fuel, design of the engines, and so on. Procurement, operations and disposal activities apply to vehicles used by the organization. These vehicles produce the Scope 1 emissions. Fleet maintenance systems need to be updated with carbon calculations. The kind of vehicle, its design, how long it will be operated, and the method of its disposal has to be considered. Vehicle emission consideration is vital when considering the entire organization. This table lists vehicles as an important reminder. However, detailed discussion on vehicle emissions is out of scope for this chapter.

5.What are the polices and practices of green POD in the context of device and peripherals ?

- *Establish (Procure)* deals with the green credentials of the asset in terms of its design and development. Ā is is a one-off decision-making process that decides on the carbon efficiency of that assets design. For example, the original design of a car engine or a mobile phone that make it carbon efficient. Ā is is a one-off factor when an organization is procuring the asset. Similarly, in case of buildings, the one-off factor that comes into play has to do with its architecture and design, as also highlighted in Table 4.1.
- *Operate (Run):* Ā e manner of operation of the asset has a bearing on the total carbon contribution of the organization. Length of operation of the asset, such as operating a vehicle for 10 years or a mobile phone for 2 years will impact the overall emissions of that asset over its lifetime. Ā e user of the asset is responsible for operating (using) it in such a way as to reduce its carbon impact. Ā us, this is an ongoing, daily decision-making process.
- *Dispose (Demolish):* Ā is is the eventual phase of an asset and it also impacts the overall carbon footprint of an organization. Ā is impact is through the organization's approach to disposing or demolishing the asset. Ā is is also a one time decision-making process with long-term effect on the environment. For example, ethical disposal or desktop and laptops are a major domain for discussion and action—especially within medium to large organizations, wherein policies might dictate the end of use of an asset rather than its actual



6.What is green business process management? discuss the roles of green BPM in reduction of an organizational carbon footprint.

Green Business Process Management (BPM) is an approach that combines traditional BPM practices with sustainability principles in order to reduce an organization's environmental impact. The focus of green BPM is on identifying and implementing more sustainable processes, reducing waste, and improving energy efficiency across an organization.

The roles of green BPM in the reduction of an organizational carbon footprint include:

Process optimization: Green BPM involves reviewing existing processes to identify areas of waste and inefficiency. By optimizing processes, organizations can reduce energy consumption and resource use, leading to a reduction in their carbon footprint.

Automation: Automation is a key aspect of green BPM, as it reduces the need for manual intervention and can lead to a significant reduction in energy consumption. By automating processes, organizations can reduce their reliance on paper and other physical resources, and reduce their carbon footprint.

Energy-efficient technology: Green BPM involves the use of energy-efficient technology, such as virtualization and cloud computing, to optimize energy consumption and reduce the carbon footprint of an organization.

Green supply chain management: By applying green principles to the supply chain, organizations can reduce the carbon footprint of their operations. This may involve sourcing materials and services from sustainable suppliers, or reducing transportation and logistics emissions by optimizing supply chain processes.

Carbon accounting: Green BPM involves tracking and measuring an organization's carbon emissions, in order to identify areas for improvement and track progress towards sustainability goals. By using carbon accounting tools, organizations can identify the most significant sources of emissions and target their efforts to reduce them.

Green business process transition is based on resource optimization. These resources include computers, contents, systems, and communication platforms that are part of the business processes. Green ICT includes tools for process modeling and many of the process-enabling technologies such as business rules, policies, and metrics. Examples of tools in Green BPM include *Abnoba* and *Lombardi*. Green BPM thus becomes an extension and sophistication of the process management domain that utilizes the concepts of process efficiencies and effectiveness and applies it for carbon reduction. The earlier BPR advantages such as reduced expense, faster processing time, concurrency/multiple access ability, efficiency, and effectiveness can be identified and mapped to reduction in carbon contents.

Green BPM is an overall approach to modeling, optimizing, consolidating, and executing business processes of an organization from a carbon perspective. Application of Green BPM results in improving the ways in which an organization (users and business areas within an organization) undertake operations. BPM can be understood as a discipline of modeling, realizing, executing, monitoring, and optimizing business processes (ACS, 2010). Each of these aspects of BPM can be applied toward a green enterprise. Silver (2006) has also described various flavors of BPM such as enterprise application integration (EAI), workflow, content management, and enterprise-wide human and system process automation that can be applied toward Green BPM. Ā us Green BPM, as discussed in this chapter, has opportunity to capitalize on the BPM approach in an organization and can be considered as a set of management and technology disciplines focused primarily on workflow and process automation that drives the implementation of optimized and sustainable business processes.

Such optimization of processes covers many aspects of the performance. Processes can be optimized to ensure efficient utilization of resources. Alternatively, processes can be reengineered to creatively eliminate the use of some redundant or duplicate resources. For example, a home loan (mortgage) process that requires application by a broker, credit check validation, and risk assessment through three separate agencies can be electronically consolidated as one. Such reengineering of processes has been a hallmark of business efficiency over past few decades.

7.what are the characteristics of the process and how do they apply to a green process?

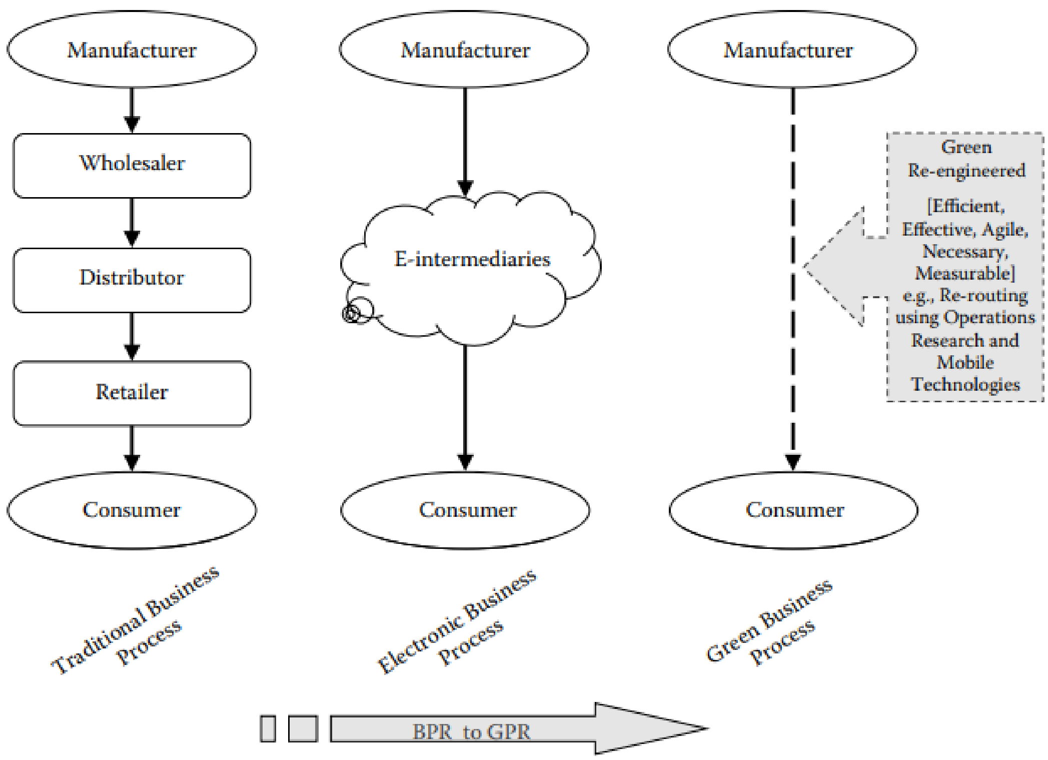
Process Characteristic	*Description (Lean Business)*	*Green Business Connotations*
Necessary	Challenges the need for the process in the first place. There is no point in making a process efficient and effective if it is not creating business value.	Eliminating an unnecessary process (not involving in value creation) will also eliminate its carbon contribution.
Efficient	Models the process to study its various activities/tasks. Challenges, automates, and merges activities to ensure they are performed with the best tools, technologies, and people.	Aims to reduce the carbon generation within the process by optimizing and/or eliminating the activities/tasks within the process. Technology is used by being embedded in the process.
Effective	Ensures that the process is actually achieving the goals it is meant to achieve. A process that is otherwise efficient and agile, but does not achieve business goals is not considered as effective.	Substantial wasteful carbon is generated by a process that is not effective—as it does not achieve business goals. Also, a process that is repeated more than once in order to produce the desired effect is a carbon-*inefficient* process.
Agile	Deals with the ability of the process to change itself in response to (or in anticipation of) external and internal changes affecting the organization. Deals with the dynamicity of the process.	An agile process will change easily and effortlessly in response to changing external situation. The agile virtue also renders the process green, as it can change with minimum carbon generation.
Measurable	Enables monitoring, control, and ascertaining the success of its optimization. Ongoing management of process performance is also supported.	In addition to the standard process measures, such as cost, time, and quality, now the "carbon content" of a process is measured. This helps in identifying the slack and optimizing it.

8.Explain the concept of green process reengineering with an example.

Green Reengineering

As mentioned earlier, Green BPM includes reengineering of business processes to optimize their emissions. Reengineering of processes to green processes will incorporate reevaluation of processes and also an understanding and modeling of their supporting hardware, software, and people in order to cut down the carbon generated through them. Similar to original Business Process Re-engineering (BPR) exercise by Hammer and Champy (1994), the success of Green process reengineering (GPR) depends heavily on undertaking a model-based, performance-driven approach that is applied to the entire organization.

Figure 5.1 illustrates the concept of process reengineering in a simple way from a green perspective. Ã e simple distribution process on the left in Figure 5.1 shows a manual distribution



process, with steps leading from the manufacturer through to the warehouse, retailer, and the end-user. A reengineering exercise will lead to the formulation of the process shown in the middle of the Figure 5.1. Ā is is an electronically enabled process that will provide business efficiencies and effectiveness in terms of the distribution network. Such efficiencies are typically achieved by displaying the product on an organization's web site and enabling the consumer to order it directly from the web site. With such reengineering, the steps associated with the wholesaler and the retailer can both be avoided—although the intermediaries can be the technology service providers and content managers (Unhelkar and Ginige, 2010).

However, the third process model, shown on the right in Figure 5.1, is aiming for yet another alternative. Ā is reengineered process is efficient and effective from a cost and time viewpoint, and also from a carbon viewpoint. For example, the third process model will aim to completely eliminate the E-intermediaries. Customer driven reengineering will optimize collaborative business processes to eliminate steps that were required only because of lack of alternative technologies (Unhelkar et al., 2009). Location-sensitive mobile technologies can improve the carbon performance by eliminating intermediary steps that result in carbon. Ā e premise here is that if the same process goal is achieved with fewer steps, the end result would be a carbon-efficient process.

Green metrics help in understanding the effects of reengineering. For example, green reengi-

Green Process Reengineering (GPR) is an approach to process improvement that focuses on reducing an organization's environmental impact while also improving efficiency, reducing waste, and lowering costs. The goal of GPR is to redesign processes from the ground up, with a focus on sustainability

For example, a company that manufactures clothing may implement green process reengineering by reducing the amount of water used in its production process, using organic or sustainable materials, and implementing a closed-loop system to recycle or repurpose materials. By reengineering its processes to be more environmentally friendly, the company can reduce its overall environmental impact while also improving its brand image and potentially attracting environmentally conscious consumers.

9.list and explain the factors which affects achieving the green business process management

an organization from a green perspective. These areas of Green BPM form a matrix with the individual, organizational, and collaborative type of processes.

- People know processes and execute processes. Ã ey need to know the purpose and the passion to perform processes in such a way to achieve Green BPM goals. So it depends on how much people knows about green concepts and how they want to approach the environment that results in the success of Green BPM goals.
- Transport is a substantial contributor to the greenhouse gases. Ã e Green BPM should essentially reduce the need of transports while doing jobs. Although transportations is necessary for business, the success of Green BPM depends on how the business processes are re-engineered to reduce transportation.
- Facilities are essential for any business and these facilities should be rearranged to suit green business goals. Ã e Green BPM should facilitate to have any facility which could produce less carbon footprint during the business operation and in idle time.
- Development of product or service in any business is one of the core components of the value chain of the business. Ã e development processes should be carefully modeled so that the carbon footprint for the development of any product or service could satisfy the Green BPM goals.
- Production is a continuous work done in businesses which also add carbon footprint to the outputs. Ã e production processes needs much attentions in modeling and optimizing in terms of carbon contents so that the outputs will lead to lesser carbon footprint.
- Information is the most important part of any process. Ã e way of managing information is the key to achieve the Green BPM goals in any business. Information modeling, capturing,

P DTF PIC

Figure 5.7 The Green BPM factors.

presenting, and analyzing would impact on carbon content as well as it can provide the knowledge of green status of the processes.

- Communication is one of the most important enabler for Green BPM. Effective communication will pave the way to achieve Green BPM goals quicker and it can also reduce the effect of carbon footprint. So the Green BPM requires the use of communication factor effectively and efficiently to achieve Green BPM goals.