绿色转型分析:数据中心碳排放管理的分析工具

Green Transformation Workbench: A Practitioner's Tool for Carbon Management in Data Centers

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Abstract: There is increasing awareness that human activity may threaten delicate ecological systems. From evidence of global warming to concerns about water and soil toxicity, individuals and groups are asking what they can do to reduce their environmental impact. New technologies, processes and laws relating to carbon emissions and other environmental issues come forth and will seriously affect how companies operate in the future. Green transformation is increasingly a key management initiative in a corporate response to climate change. This paper presents a software tool, Green Transformation Workbench, which can help companies work toward the goals in logical, manageable stages as well as position them to reach the vision of a Sustainable Business and Corporate Social Responsibility. The Green Transformation Workbench provides a framework that aligns processes, people and infrastructure of an enterprise to realize targets on carbon emissions. It implements a methodical approach that was devised to analyze green transformation opportunities and make business cases for transformation initiatives and thereby provides decision-support to the consultants. The Workbench is a practitioner's tool for business transformation addressing the issues. The Green Transformation Workbench builds on IBM's component business model and offers a consolidated view into data center operational components, processes, metric and infrastructure. It provides an intuitive way to evaluate and understand various opportunities in infrastructure consolidation and operational improvement. It embodies structured analytical models, both qualitative and quantitative, to enhance the consultants' practices. It provides diagnostics in data center operations based on benchmark data and business case analyses to the proposed green solutions. The Green Transformation Workbench has been instantiated with data from real-world data centers and applied to address a client situation as a case study.

Key words: green business; carbon management; business transformation; business consulting services; business case analysis

1 Introduction

With increasing public awareness of environmental issues and concern about global warming, the growing inefficiency in a data center could be a public relations time bomb for the company[1-3]. Even if the business is not overly concerned about its environmental profile, the financial aspects of inefficiency should be enough to spur action. Energy prices are rising rapidly, and IT power

consumption is set to become a major cost center for many organizations[4,5]. Beyond these direct costs, a sprawling, inefficient data center is also difficult and costly to manage and expand, and slow to adapt to new business requirements. This paper explores optimization strategies around the key areas of people, business processes and infrastructure in data centers, including entry points for analyses, relevant solutions, demonstrating benefits which were observed within the data center line of business of a world class IT service provider. Utilization of these capabilities will help data center practitioners meet the increasing challenges of energy efficiency, cost containment and compliance.

A data center is a facility used to house computer systems and associated components, such as telecommunications and storage systems. For most organizations, the growing importance of IT is putting pressure on space and resources in the machine room or data center. The historical tendency to add a new server and storage system for each new application means that many businesses have oversized, inefficient IT infrastructures–often with additional departmental servers outside of the central facility. As demands for new applications and data storage grow, floor space, power consumption and heat output in the data center are becoming major issues. It is not just a question of rising costs for power and cooling–in many cases, organizations are coming up against the physical limitations of their data center facilities, in terms of how much floor space is available and how much power and cooling can be supplied. As more machines, running faster and hotter than the previous generation, are continually added, the carbon footprint of the typical data center is growing rapidly.

With the increased focus on energy awareness, many companies are now making an assessment of their data center efficiency[6,7]. Collecting the data, analyzing it, and making improvements to the physical data center and its components are just a starting point. The data center is a living entity, constantly under change internally, but also under constant pressure for change due to variable outside influences such as political pressures, limits on available power, increasing environmental regulatory compliance requirements, and financial impacts such as ever-escalating power costs.

This paper presents a software tool, Green Transformation Workbench, which can help companies assess their data center efficiency and identify enhancement opportunities in logical, manageable stages. The Green Transformation Workbench is a framework that aligns processes, people and infrastructure of an enterprise to realize targets on carbon emissions. It implements a methodical approach that was devised to analyze green transformation opportunities and make business cases for transformation initiatives and thereby provides decision-support to the consultants.

The Green Transformation Workbench builds on IBM's component business model[8,9] and offers a consolidated view into data center operational components, processes, metric and infrastructure. It provides an intuitive way to evaluate and understand various opportunities in infrastructure consolidation and operational improvement. It embodies structured analytical models, both qualitative and quantitative, to enhance the consultants' practices. It provides diagnostics in data center operations based on benchmark data and business case analyses to the proposed green solutions. Unlike the traditional consulting methods and tools in the domain, the Workbench provides additional tools for effectively addressing issues such as scalability of methodology, knowledge management, method enforcement, asset reuse and governance, consolidated views of upstream and downstream analyses well, to name a few. The Workbench is a practitioner's tool for business transformation addressing the issues. The Green Transformation Workbench has been instantiated with data from data centers from a world-class IT service provider and applied to address a client situation as a case study.

The rest of this paper is structured as follows: Section 2 provides an overview of our approach, a practitioner's tool for green transformation and explains its models and methodology. Section 3 describes in more detail the CBM-based qualitative business analyses, i.e., Green Transformation Diagnosis system. Finally, in Section 4, conclusions are drawn and future work is outlined.

2 Green Transformation Workbench

Green Transformation Workbench (GTW) provides

an integrated view of various business models and data, including a component business model[8,9], a business process model (e.g., APQC (American Product Quality Council) Process Classification Framework[10]), a value driver model, an infrastructure map, an organization structure map, and a solution catalog, with the models linked each other, as shown in Fig.1. The workbench helps organizations understand and transform in three key areas of operations, i.e., business processes, infrastructure, and organizations.

The business processes are executed by people on the infrastructure within organizations, and their underlying tasks and applications directly influence energy needs. Effective operational management includes the ongoing improvement of business and IT information and processes to ensure that a continual focus is placed on reducing the carbon impact of the organization. GTW helps understand the efficiency of business operations with processes and infrastructure designed to maximize energy efficiency while meeting business needs. The infrastructure of a company, such as data center systems, buildings, factories, trucks, etc., is a major consumer of energy. In fact, the industrial sector consumes 47% of worldwide energy demand. GTW helps organizations visualize, how the infrastructure to deliver power efficiency and optimize operations by leveraging consolidation and virtualization. The organizations directly and indirectly contribute to the carbon footprint in a range of ways, from the impact of cycle-time involved in various projects, to the physical office space and its energy requirements. The workbench helps organizations optimize the use of people resources and collaboration beyond boundaries to drive business growth while reducing travel and physical real estate costs.

For such analyses, GTW automates the traditional component business model-based analyses by using visual queries and inference. The qualitative business analyses using the visual queries and inferences in the tool are generally referred to as daisy chain analysis[9]. An example of the daisy chain analysis in the workbench is the ‘heat map’ analysis where it automatically discovers underperforming business components in the map and color them based their performance, as shown in Fig.1. It first identifies the metrics associated with each component, compare their as-is values against the industry benchmark values[3,11,12]. Underperforming components are ones associated with metrics whose as-is value is worse than the benchmark value. Another example of the daisy chain analysis is the ‘shortfall assessment’ of infrastructure and organization. The workbench infers and associates infrastructure systems and organizations with each business component, and renders them in the business component map. Then the user can visually identify and categorize shortfalls (or transformation opportunities) in infrastructure and organizations such as ‘gap,’ ‘deficiency,’ ‘duplication,’ and ‘over-extension.’ Once the transformation opportunities are identified, then the tool also discovers solutions that may address the shortfalls by using the similar daisy chain analysis.

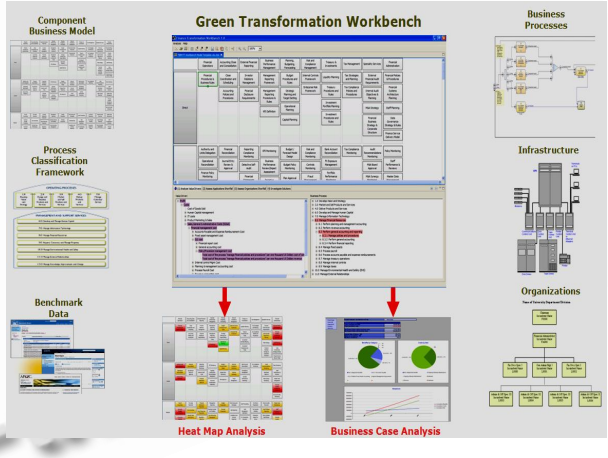

Fig.1 Green transformation workbench

Once one or more transformation solutions for IT and/or organization are discovered, GTW also provides a quantitative analysis on them, i.e., the business case analysis in terms of standard financial metrics such as NPV (Net Present value), IRR (Internal Return Rate), ROI (Return on Investment), and Payback time. Additionally, the workbench provides carbon benefit analyses for each solution category by using green metrics such as Internal Cost of Carbon per ton and percentage reduction in carbon. The workbench provides normative and constructive business performance analysis models, and so it can be easily configured for different types of clients, initiatives, and projects.

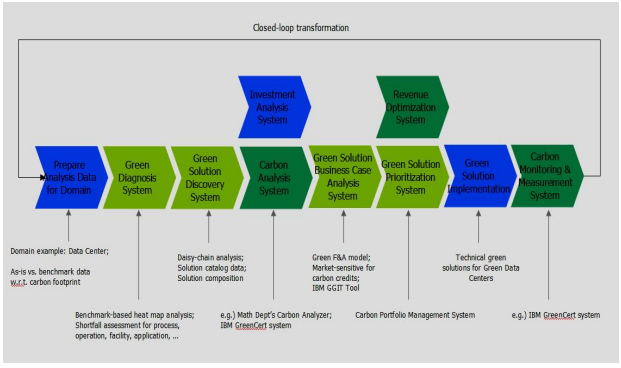

Fig.2　Green transformation methodology

GTW employs a phased methodology that relies on assessment, analysis and prioritizing transformation solutions, as displayed in Fig.2. The initial diagnosis phase identifies the business pain points in the components by comparing the as-is values on value drivers with the industry benchmark values from best practices[12]. The result can then be used to help identify transformation opportunities in infrastructure and organizations with scope for improvement. The daisy-chain analysis help discovering the solutions to mitigate the pain points which can be further analyzed for carbon-cost benefits by using the business case modeler. By conducting benefit analyses iteratively with various combinations of solutions, the user can prioritize them for their significance and create a road map for final action. Among the steps shown in Fig.2, this paper focuses on the following three steps, while other will be discussed in other space:

Green Diagnosis System for identifying "hotspots" of carbon reduction in the as-is enterprise IT management practice and for assessing the as-is practice to identify and categorize 'shortfall' areas for carbon reduction,

Green Solution Discovery System for automatically identifying (and composing) solutions (by using the daisy-chain analysis) for addressing the identified 'hotspots' and 'shortfalls,' and

Green Business Case Analysis System for assessing cost vs. (carbon) benefit, resolving and optimizing investment and benefits, and prioritizing initiatives based on the combined sets of options.

The Green Diagnosis System utilizes IBM's Component Business Model-based business transformation methodology[8,9,13] that represents enterprises in a consolidated view, grouping together similar business activities as a business component and classifying business functionality into non-overlapping components. It identifies business processes and activities associated with each business component. It utilizes the daisy-chain analysis[9] for the heat map analysis and shortfall assessment to identify transformation opportunities in the current environment – infrastructure and organizations.

In GTW, models are mapped to each other. We refer this linking of models and the ability to query them to "daisy-chain analysis." With the daisy-chain of models, the user can see all the business processes and activities that are associated with a business component. In turn, the user can see all the metrics (along with their values) and value drivers of the selected business processes, and so s/he can qualitatively see the overall performance of the component. For the 6 base models in GTW, the user can provide a set of initial model association to business processes as part of the data preparation for GTW analyses–5 types of links, i.e., Comp2BizProc, VD2Biz Proc, Infra2BizProc, Org2BizProc, and Sol2BizProc. That is, we use a hub-and-spoke approach to linking the models, i.e., all models are linked to the business process model instead of each model linking to each other model.

Daisy-Chain analysis allows navigation across the integrated view of models to see the direct and indirect relationships among models. The tool infers the indirect ones from the direct ones by using the transitive relationships. The heat map analysis is an example of a daisy-chain analysis. The heat map is generated by comparing the values of the carbon drivers and metrics (indirectly) associated (through business processes) with business components. The green shortfall analyses such as the organization and infrastructure shortfall assessment are also applications of the daisy-chain analyses. They utilize the indirect relationship of the infrastructure and organization entities to business components, which are, in the tool, visualized as graphical overlays so that the user can visually identify and categorize shortfalls. Another example of the daisy-chain analysis is the solution discovery which discovers one or more solutions for business components with shortfalls by using the inferred relationships.

The Green Solution Discovery System also utilizes the daisy-chain analysis and one or more solution catalogs to identify green transformation initiatives to address the discovered shortfalls and support the intended business transformation. Green performance metrics (value drivers) allow the analysis tool to discover and recommend solutions to fill "green" shortfalls in processes, organizations, and infrastructure.

The Green Business Case Analysis System utilizes IBM's Green Business Case Calculator (GBCC)[9] which is an MS Excel-based tool, with a pre-built template for conducting financial and carbon analysis of the chosen solutions. For each category of solutions, GBCC identifies cost and carbon benefits, allows distribution over year producing a cost-carbon flow up to

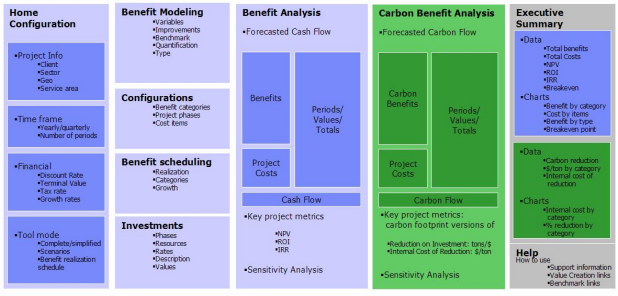

Fig.3 Green business case calculator

25 years from now and consolidates the overall analysis with financial and carbon metrics. The financial model calculates the standard metrics such as Return on Investment (ROI), Net Present Value (NPV) and Internal Rate of Return (IRR) of the project, and break even period. The carbon model provides ROI (Reduction on Investment) and ICC (Internal Cost of Carbon) of different categories of green solutions. An executive summary represents financial and green results graphically. Fig.3 illustrates the features of IBM Business Case Calculator.

3 Green Transformation Diagnosis

The Green Transformation Diagnosis System in GTW utilizes the Component Business Model-based business transformation methodology that represents enterprises in a consolidated view, grouping together similar business activities as a business component and classifying business functionality into non-overlapping components. It utilizes the daisy-chain analysis for the heat map analysis and shortfall assessment to identify transformation opportunities in the as-is practice.

3.1 Heat map analysis

The Heat Map Analysis is an essential capability of CBM where the user discovers one or more "hot" components that are associated with one or more business strategies and/or pain points. In the traditional CBM analysis, this step was conducted manually by the business consultants relying on his/her knowledge and expertise in the business domain. The GT Workbench automates the capability as visual queries, by taking metrics values into account with the analysis. First, the system allows the user to explore the value driver tree to identify one or more value drivers that may be associated with a certain business strategy/pain point. The discovery of "hot" components that affect the business strategy can be accomplished. Then the system colors the identified hot components differently to distinguish ones that affect positively or negatively to the strategy. The GT Workbench system compares the industry benchmark and the as-is value of the operational metrics and performance indicators associated with the components to decide on their color.

In this study, the reduction metrics associated with the data center operational processes are compared with the industry benchmark levels obtained by surveying. The business components whose metrics underperform in comparison to the industry benchmark values are highlighted in yellow. The components whose metrics underperform in comparison to the industry average values are colored in red. The components whose metrics perform above the industry benchmark values are highlighted in green. This green performance analysis indicates that the metrics associated with performance tuning function of ABC Inc. underperform by 30% in comparison with the industry's best practice and by 15% in comparison with industry's median.

3.2 Shortfall assessment

The Shortfall Assessment allows the user to map the existing infrastructure or organization structure of a data center against the "hot" components identified in the

Heat Map Analysis. It helps understand how the current infrastructure or organization structure, such as applications, network capabilities or certain departments, supports the business, especially, for those hot components. The analysis requires collecting the information on the current infrastructure or organization structure. Then the mapping of IT applications or organization structure to the components becomes, again, an execution of a simple data query to the basic model mapping.

GT Workbench visualizes the mapping on the CBM map by overlaying infrastructure items and/or organization structure on components. Then, the user can visually classify possible infrastructure shortfalls into several types. Typically, four types of opportunities tend to arise. First, a gap indicates that a hot component does not have any infrastructure/organizational support. The enterprise may want to consider an infrastructure/ organizational investment to improve the component's performance and support the intended business transformation. Second, a duplication indicates that a component is supported by multiple infrastructure items or multiple departments, possibly, deployed over time. The business may want to consolidate the applications to improve performance and reduce cost in communication and maintenance overhead. Third, a deficiency indicates that the current application lacks key functionality, or is poorly designed, and so incurs a project opportunity. Finally, an over-extension indicates that a system designed to support one business component is extended beyond its core capability to support others. Different definitions for the shortfall types may apply.

In GTW, the shortfall assessment is facilitated by an innovative visual overlay of information on business components that shows infrastructure items implementing the business functions of business components. Let's say, the user visually notices that six infrastructure items are supporting the 'Performance Tuning' component in ABC Inc, i.e., CiRBA Solution, Ecos Consulting and EPRI's Power Applications Center, Energy Efficiency Rating, IBM System Storage, IBM Virtualization, and IBM Virtualization Engine TS7530 Server.

The user can tell based on system performance that the low level of virtualization was implemented. This fact highlights an opportunity for virtualization. The user then can mark the Performance Tuning component having 'deficiency' in infrastructure. In GTW, this component is marked as a candidate for 'deficiency' shortfall.

3.3 Solution discovery

Once infrastructural/organizational shortfalls are identified and classified, one or more solution catalogs are used to identify transformation initiatives to address the shortfalls and support the intended business transformation. GT Workbench allows the user to explore the solution space to identify one or more solutions that may address one or more shortfalls of interest. The discovery of solutions for supporting components associated with a shortfall can be automatically conducted by executing the "Daisy-Chain" queries that correlate solutions and components by using their relationships to business processes. In addition, GT Workbench allows the user to manually correlate them, if desired.

The choice of solutions depends on a number of factors such as breadth of the pain points, the benefits offered by a solution, client's budget constraints, duration within which improved results are expected, etc. In this example, the solutions of 'Server Virtualization' and 'Commissioning and retro commissioning' were discovered to address the infrastructure and organizational shortfalls, respectively. Therefore, the user has chosen the solutions as potential candidate solutions for improving the 'Performance Tuning' and 'Infrastructure Operations Management' of ABC Inc.

Selecting a proposed solution or a set of proposed solutions in the GT Workbench shows the linkages of that solution with process, metrics and shortfalls. These linkages help us understand (a) which processes the selected solution impacts (hopefully, positively), (b) which metrics can be used to measure the impact of process improvements to be achievable by implementing the chosen solution, and (c) which marked shortfalls the chosen solution will help with.

The solution analysis helps the GTW user get a quick idea at a qualitative level about which solutions can help address clients' shortfalls. The next step is to analyze the potential benefits the client can get by

implementing the chosen solutions quantitatively by using the Green Business Case Calculator introduced in Section 2.

4 Concluding Remarks

In this paper, we introduce the Green Transfor- mation Workbench, a consulting practitioner's tool for identifying and analyzing green transformation oppor- tunities. It embodies structured analytical models (both qualitative and quantitative) to enhance the consultants' practices. The tool helps visualize the linkages of various enterprise models such as component business models, business process models, value driver models, organiza- tion models, infrastructure models, and solution models. Using this tool, consultants can examine which operational functions and business components are underperforming in comparison to industry benchmark measures and why. By investigating the organizational responsibilities and infrastructure portfolio in conjunction with business components, shortfalls such as duplica- tions, over-extensions, gaps and deficiencies can be identified and reasoned. Following that, specific solutions can be discovered to address the identified shortfalls. Financial and carbon benefits of implementing specific solutions can be analyzed further via conducting a green business case analysis. We have conducted an empirical study with the Green Transformation Workbench by using data sets obtained from a number of enterprise data center services.

The GT Workbench methodology and its software solution is part of an ongoing research initiative on green design and transformation at IBM Research and Global Business Service Divisions. With a methodology and a research prototype in place, we work with practitioners to validate them with real-world green transformation initiatives. In addition to the tool and methodology, in practice, the availability of useful and accurate content and information of business components, value drivers, processes and solutions is critical to meaningful analyses. Further validation results from practices will be reported in the future.

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