

# Chapter 51

## Multidimensional Analysis of Supply Chain Environmental Performance

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### ABSTRACT

*Monitoring the environmental performance of a product is recognized to be increasingly important. The most common method of measuring the environmental performance is the international standards of Life Cycle Assessment (LCA). Typically, measuring is based on estimations and average values at product category level. In this chapter, the authors present a framework for measuring environmental impact at the item level. Using Traceability Graph, emissions and resources can be monitored from the data management perspective. The model can be mapped to any precision level of physical tracing. At the most precise level, even a single physical object and its components can be analyzed. This, of course, demands that the related objects and their components are identified and mapped to the database. From the opposite perspective, the authors' model also supports rough level analysis of products and their histories. In terms of the Traceability Cube, multidimensional analysis can be applied for traceability data.*

### INTRODUCTION

Green computing is usually analogized with Green IT as pure technical issues closely related hardware and software solutions following Murugesan's (2008) definition "the study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated

subsystems—such as monitors, printers, storage devices, and networking and communications systems—efficiently and effectively with minimal or no impact on the environment." Instead, we agree with those authors (e.g. Donnellan, et al., 2011) who see that green computing not only involves the previous definition for Green IT, but also possesses methods to use ICT in business processes to reduce environmental impact of enterprises.

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Our contribution is to serve fine-grain tracing approach for monitoring and analyzing life cycle data of products. As our example (forest industry) illustrates our model is general—not only for manufacturing and tracing of computers and data centers. Any physical product has its own supply history represented as a supply chain. In practice, the history of the product is the history of its parts composed in the supply chain. The precision of traceability of products depends on how detailed the history of the components can be traced. We give a logical framework for tracing and analyzing the emissions and resources of products both at the item and patch levels.

The problem with measuring the environmental impact caused by a product at the item level is that supply chains are dynamic. A manufacturer can use various subcontractors and supply various end manufacturers or retailers in different countries. For example, a product that is transported from another continent to a supermarket is bound to have different environmental impact than another product that is transported to a supermarket from a nearby producer. However, the common method of calculating the environmental impact on a product is to measure the resources used, emissions and production in some time period and calculate the average environmental impact on the product. This does not take the dynamic nature of the supply chains into account.

To be able to track the objects through the dynamic supply chain, the products/patches must be identified at the physical level. The development of an auto identification enables us to identify an object moving in the supply chain. This means that we can connect the physical world objects with their virtual counterparts in databases. With the traceability we can track the relationships among properties of processes, in this case the environmental burden caused by processes, and actual product instances.

Unlike existing methods our model enables analyzing environmental impact on the product level – not only average values. The model sup-

ports for monitoring emissions (e.g. CO<sub>2</sub>) and resources (e.g. Energy) at any precision level only depending on how precisely physical products and patches can be identified and monitored. Our approach is based on the Traceability Graph (Junkkari & Sirkka, 2011) that enables tracing of products on any level of precision. In practice the method, produce a huge amount of data. Multidimensional methods (e.g. OLAP, online analytic processing) enables viewing this data through several dimensions at different levels of granularity. We design a data cube, called Traceability Cube, for advanced analysis of traceability data.

## **WORKFLOWS**

Generally, workflows are used to model the flow of materials, documents and other pieces of information from one process to another (van der Aalst & van Hee, 2002; Bonner, 1999). Modern software modeling methods such as UML contain activity diagrams for mapping real-world activities to the underlying software solution (or vice versa). There are also a number of commercial applications that have a component for drawing workflow diagrams. The common feature of these applications is that they support the illustration of different types of processes.

The workflows can be divided into two main categories, process- and data-centric. So far, the process-centric workflow modeling focusing on processes and the timing between them has been the dominant approach. However, recently the data-centric workflow modeling has gained popularity. In the data-centric workflow modeling the focus is on the transformation of data sets—initial, intermediate, and final (Akram, et al., 2006). The data sets are used as parameters to services that consume the input data set and create output data sets. The data-centric workflows are most commonly used in scientific problem solving.

In scientific problem solving the primary feature of the scientific workflow methods is to

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