

Life cycle assessment in woven textiles

TAPPO L. KUUSINEN, ROBERT H. BARKER, AND DONALD A. ALEXANDER

AS TRANSPORTATION AND COMMUNICATION technologies continue to advance, the textile industry becomes more global. Many textile manufacturers sell their products in many countries. This trend should continue. Textile manufacturers have taken advantage of the trend by forming international joint ventures, purchasing foreign manufacturing, and building new manufacturing facilities around the world.

To compete in the international marketplace, textile manufacturers must produce superior products delivered on time and made with minimum cost and liability. Unfortunately, many opportunities for substantial cost savings are hidden because they have been incorporated into operating standards or exist due to historical industry practices. Many of these hidden costs in the textile chain are in the environmental and energy areas.

TEXTILE RESOURCE CONSERVATION PROJECT

The U.S. textile industry is cooperating to develop technologies that will improve the competitiveness of the industry. A large initiative is the American Textile (AMTEX) Partnership. This is a technology development initiative accessible to all fiber producers, textile manufacturers, sewn and fabricated products manufacturers, and retailers in the United States. The partnership goal is to improve the competitiveness of the integrated U.S. textile industry through research and development.

The AMTEX Partnership began with a large research and development initiative with the U.S. Department of Energy National Laboratories. The U.S. Environmental Protection Agency (EPA) also has recently joined AMTEX. The initial industrial partners involved in the AMTEX Partnership include more than 120 companies that were willing to commit resources to cooperative technology development.

The aim of the Textile Resource Conservation (TReC) project is improving the competitiveness of the integrated textile industry in the United States by reducing waste and utility consumption in the textile product manufacturing chain.

The integrated textile industry established the TReC project. It includes research and development activities in several important areas. The project focuses on environmental and energy improvements in the integrated textile industry that can be achieved through waste minimization and processing advancements. Efforts include prevention of waste and the reuse and recycling of raw materials. Extensive industry information provided the project focus. Workshops of industry representatives from companies making fiber, textile, and cut and sewn products developed the issues and needs.

TREC ENVIRONMENTAL DECISION TOOLS TASK

This task began as a strategic planning effort to identify opportunities and needs for integrating resource management into the business struc-

LIFE CYCLE ASSESSMENT

ABSTRACT

Life cycle assessment can evaluate the system-wide effects of product and process design options. Software development is streamlining and reducing the cost of life cycle assessments in the textile industry. One environmental decision support tool builds on the experience of life cycle assessment of textile products such as the inventory analysis of a woman's 100% polyester blouse. Other types of product evaluations might include analysis of the proposed eco-labeling systems being considered overseas that may pose trade barriers to the import of U.S. textiles. Additional uses include analysis of the cost of resource losses and opportunities for improving the system-wide cost-effectiveness of the integrated U.S. textile industry.

Application:

Software for life cycle assessment can analyze the cost of resource losses and offer improved opportunities for the U.S. textile industry.

ture of textile manufacturing operations. Realizing that hardware is only part of the answer to improved resource efficiency led to an effort to decide what else the industry most needed to make significant improvements in resource management. Two important elements necessary for long-term improvement are the ability to understand fully the financial implications of unused raw materials and a mechanism for incorporating resource management improvements into business decisions.

Hardware is insufficient

When investigating new ways to improve performance, most people look first to advanced technology. The technology necessary to improve resource management in the textile complex requires not only hardware but also an advanced

Cost element	Expenditure, US\$, M	Total cost %
Labor	16,639	25.9
Energy and fuels	2,118	3.3
Materials	45,551	70.8

I. Cost of goods manufactured in the U.S. textile industry for 1994

information and decision system infrastructure. In many respects, the decision systems provide more opportunity to integrate resource management into the continuing operations of a company than does specific hardware.

Improving the resource efficiency of a textile manufacturing operation is similar to improving product quality. Manufacturing machinery is an important ingredient in a quality improvement program, but hardware alone does not ensure that a successful quality program will occur. A resource management program must similarly go well beyond the use of advanced hardware.

Financial implications of waste

Since companies are in business to produce a profit, there must be financial incentive to invest time, energy, and capital in improvement programs. Improving resource management means completely understanding the financial implications of wasted raw materials and utilities.

The U.S. Department of Commerce tracks industry statistics by Standard Industry Classification (SIC) code. The Bureau of Census conducts an annual survey of information on the "cost of goods manufactured." Survey results from 1994 for Textile Mill Products (SIC 22) show potential cost savings that could result from improved resource management. **Table I** shows the cost of goods manufactured in the U.S. textile industry (SIC 22) for 1994.

Through significant capital investments in modern, high-speed machinery, the textile complex in the United States has taken advantage of many labor cost-saving opportunities. Significant improvements have also occurred in product quality resulting from advanced machinery, better controls, and improved information systems. Since materials and energy constitute approximately three-fourths of the cost of U.S. textile goods manufacturing, a fruitful area for future cost savings is improved resource management. Improving resource management will reduce manufacturing costs while reducing long-term environmental costs and liabilities.

For a better insight into the potential cost savings available through improved resource efficiency, the Institute of Textile Technology conducted a "Cost of waste" survey of AMTEX companies in 1995. This survey asked companies to calculate the cost of managing waste materials—subtracting revenues received from recycling—and the cost of purchased raw materials not incorporated into products.

One illuminating result from the cost of the waste survey was that the cost of nonproduct raw material losses were often several times higher than the cost of managing and disposing of waste. Because material costs are such a high percentage of the cost of goods manufactured, a company's total cost of waste—including nonproduct raw material costs and waste management costs—can also be very large. It can even exceed the typical annual operating profit of the company. Another enlightening example of the size of the resource efficiency improvement opportunity that lies

in the textile chain comes from a small survey of fibrous solid waste in circular knit apparel production conducted by the Institute of Textile Technology with AMTEX in 1994. The fiber purchased for knit apparel that remains as waste can be as much as 18%. Extrapolating the survey results to all circular knit manufacturing in the United States equates to 237 million pounds per year of scrap fiber. A conservative estimate of the value of this waste is US\$ 474 million annually.

Now that we can show cost savings available through textile resource conservation, we must move on to developing tools and techniques to capture this opportunity.

Environmental Decision Tools

Advanced decision systems or tools are increasingly important as business and environmental decisions become more complex and interrelated. The corporate downsizing trend in U.S. industry leaves fewer and fewer people to make more complex decisions. Advanced decision systems will provide the opportunity for companies to evaluate more thoroughly the environmental and cost consequences of decisions.

Environmental decision tools are automated systems that give users an opportunity to consider more complex data and interactions, perform "what if" analyses, improve the speed of decision making, and ultimately lower costs in the textile complex. Many approaches will provide benefits to the textile complex, although most approaches may still be in the research stage. Industry must find a way to use all available tools that could improve business and environmental performance through improved resource management.

Textile Resource Integration Model

The first environmental decision tool is the Textile Resource Integration Model (TRIM). TRIM uses an existing life cycle assessment (LCA) software

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platform at Pacific Northwest National Laboratory. The TReC environmental decision tools task built upon these base LCA capabilities and added cost accounting features.

Design of the TRIM software allows it to analyze large systems that include product manufacturing systems in a modular manner. TRIM uses four basic building blocks to analyze such systems.

The first unit of evaluation in TRIM is the resource. A resource can be a material, energy source, labor supply, or service. Each resource has a unique resource identification (ID). Creation of a new resource provides certain data associated with that resource ID. This information includes who created it, when it was created, the name and any aliases, a short description, any groups to which it may belong, a section with notes, and material data, if it is a material. Measurement of resources may use predefined standard units or custom piece units. Piece units can be defined during creation and must be defined in an existing piece unit or with another predefined unit.

The second object in TRIM is the process. A process takes in resources and does something with them. A process must have at least one input and one output. Outputs can be useable product or waste product residual. A process also has a unique process ID. The process model and transfer function define a process. The transfer function defines the rate of input and output of resources. Resources may be defined individually or as they relate to other resources. In creating a process, the author must allocate the percentage of inputs and residuals to each product created. This allocation determines the responsibility associated with the production of each product.

Resources next flow between processes to make a segment. A segment is a set of processes linked with the flow of a resource. Segments rep-

resent an entire procedure where a process defines one step in the procedure. A segment is defined by the processes involved and the links made between those processes. When a segment forms, a set of equations is created to define that segment. The equations determine the relationship of the flow of resources through the multiple processes.

Finally, scenarios put restrictions on the input or output for a particular process or segment within a segment. Once one or many restrictions are put on a segment, the segment equations calculate the rate of resource flow between processes for all resources in the segment. After determining these results, one can view them in numerical or graphical format or print them as a chart.

Besides tracking physical flow of materials and energy in complicated systems, TRIM can also track monetary flow. This cost accounting capability specifically supports the "cost of waste" evaluations described above. The Institute of Textile Technology (ITT) will be the distribution point for the TRIM software. It will be available to companies in the U.S. textile supply chain including manufacturers of nonwovens.

LCA ACTIVITIES IN WOVEN TEXTILES
A large, publicly available LCA application in woven textiles is a recent life cycle inventory study of a woman's 100% polyester blouse. The American Fiber Manufacturers Association (AFMA) commissioned this study in 1993, and Franklin Associates, Ltd. performed it. At the time of writing of this paper, data from the polyester blouse study is undergoing incorporation into the TRIM software with cost information to evaluate TRIM's cost of waste analysis features.

Results of the polyester blouse study

The primary outputs of the original AFMA polyester blouse study were

energy use and releases per one million wearings of the subject blouse. The calculated results assumed a blouse life span of 40 wearings and a frequency of laundering of every second wearing.

While the results of the life cycle inventory can vary by changing some underlying assumptions used, the clear conclusion remains the same under all plausible scenarios and assumptions. The primary environmental issues associated with the polyester blouse life cycle occur in the product use phase of this life cycle. In hindsight, this might not be surprising for an assessment of a durable—as opposed to single-use—product. The project team found the overwhelming dominance of the consumer use phase of the product life cycle surprising.

Some summary statistics from the AFMA blouse study¹ are the following:

- Over 80% of the energy requirements per million wearings occurred in the consumer use phase of the product life cycle.
- Even assuming discarding of the subject blouses after 40 wearings—well before showing obvious signs of wear and tear—two-thirds of the solid waste generated during the product life cycle was due to consumer use—primarily waste associated with laundering.
- Due to the diversity of atmospheric and water borne releases over the product life cycle, summary statements are difficult to make. Product laundering obviously contributed heavily to the largest categories of these releases.

Implications of the blouse LCA and plans for future work

A clear implication of the polyester blouse study for government policy

1. Smith, G. G. and Barker, R. H., *Resource Conservation and Recycling* 14:233(1995).

makers and product manufacturers is that changes in consumer use appear to offer the greatest opportunity for reducing the life-cycle environmental releases associated with many multiple use products such as apparel. Examples of product improvements and consumer behavior changes include the following:

- Improving detergents and clothes washers to increase the effectiveness of cold water washing
- Improving the soil resistance and wrinkle resistance of fabrics
- Educating consumers about the environmental benefits of cold water washing and line drying of textiles
- Educating consumers about the potential environmental benefits of spot cleaning, washing only full loads of laundry, and other approaches to increasing the time between laundering cycles.

The textile industry and other interested parties can use the TRIM model to assess the potential environmental benefits and cost savings—accruing largely to the consumer in this context—in adopting any of the above approaches. The ability to conduct sensitivity analyses rapidly will be an important feature of this exercise given the uneven quality of the underlying data and assumptions used in analyzing "typical" consumer behavior.

While much of the opportunity for environmental improvements may lie in the consumer phase of the apparel life cycle, work by AMTEX and ITT has shown that potential sav-

ings in the cost of waste in textile manufacturing remains sufficiently large to have a significant impact on improving the profitability of textile enterprises. We therefore expect to use TRIM to evaluate specific case-study examples of the potential cost of waste improvements in actual textile manufacturing operations.

A final area where we expect to assess the utility of the TRIM model is the evaluation of the proposed textile eco-labeling schemes. Individual European countries are developing these initiatives. Many U.S. textile producers have concerns that some labeling schemes do not use recognized LCA principles. They may have a primary motive to favor domestic textile products. Since TRIM specifically conforms to the LCA principles developed for the ISO 14000 series of international environmental standards, it may be a promising tool to identify where proposed eco-labeling approaches may deviate from accepted LCA principles. TJ

Kuusinen is senior program manager at Pacific Northwest National Laboratory, Batelle Blvd., Richland, WA 99352; Barker is vice president at American Fiber Manufacturers' Association, 1150 17th St., NW, Suite 310, Washington, D.C. 20036; and Alexander is director AMTEX TREC project at Institute of Textile Technology, 775 Spartan Blvd., Suite 203, Spartanburg, SC 29301.

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