



Innovations in Sustainable Enterprise

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Center for Sustainable Enterprise

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University of North Carolina

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Featured Faculty Research

Supply chain considerations for product recycling: Reconfiguring a remanufacturing line

By Jayashankar Swaminathan

Growing environmental concerns about the magnitude of waste products generated by the manufacturing sector, along with cost considerations, have prompted some firms to collect reusable product modules and refurbish them for sale in the aftermarket. However, product recycling or remanufacturing often presents unique production and supply chain challenges for firms. The following study of production at a Visteon remanufacturing facility in Lamosa, Mexico illustrates some of these challenges.

Visteon is a major supplier of integrated automotive systems, including power-train control, chassis, and electronics, to Ford Motor Company. Visteon uses the term "remanufacturing" for transforming used units ("cores") into refurbished units that satisfy exactly the same quality standards as new units. Visteon's plant in Lamosa remanufactures product families for several models of Ford vehicles. The facility was plagued with heavy fluctuations of supply and demand, leading to periods of severe capacity shortage. Management asked us to assess options for improving capacity.

Our study focused on the rack and pinion (R and P) gear product family. The mixed model R and P remanufacturing line is structured like a repair facility: cores are first stripped of worn-out (non-reusable) parts, then cleaned, inspected visually, tested for straightness and cracks, machined, assembled, tested for functionality, and finally packed and shipped. The R and P line has few product variants with the top eight product families accounting for over 80 percent of the demand. The quality of input cores varies; this variability often results in loss of throughput.

Visteon's Dilemma

Visteon's managers hesitated to make additional capital investments to overcome the adverse impact of variability and struggled to identify the best option to reconfiguring the plant. Clearly, Visteon could not reduce the variability of processing times because it had limited control over the quality of cores it received.

(continued next page)



Jay Swaminathan is the Benjamin Cone Research Professor and Area Chair of Operations, Technology and Innovation Management (OTIM) at UNC Kenan-Flagler Business School.

Dr. Swaminathan's interests include pricing, outsourcing, and supply chain strategies for sustainable enterprises. His research on pricing appeared in the January 2006 edition of *Management Science* in a paper titled, "Managing New & Remanufactured Products," where he and his former colleague Geraldo Ferrer evaluate the pricing economics of managing remanufactured products alongside new products.

[Bio online](#)

"Reconfiguring a Remanufacturing Line" (continued from page 1)

Given these constraints, Visteon management wanted answers to the following questions.

1. Should Visteon use a number of short lines or a few long lines? What difference in throughput would result?
2. What improvements could Visteon make by dynamically assigning tasks to workstations?

To address these issues, we developed an optimization and simulation model that we deployed to recommend improvements to Visteon's remanufacturing line.

Models for Line Reconfiguration

We modeled Visteon's remanufacturing assembly operation as a serial production line in which remanufacturing the product from the core requires a set number of tasks. For Visteon's remanufacturing operation, we had to decide how many production stations to have in each assembly line and the number of copies of each line.

Visteon's remanufacturing operations had interesting characteristics in terms of modeling and analysis. First, to maximize throughput we need to improve both line balancing and line reconfiguration. Second, the randomness in processing durations stemmed from uncertainty about the conditions of retrieved cores; however, once workers tested a specific core for wear, they could determine its processing durations accurately. Third, Visteon's operations policy set limits, such as zero buffer inventory.

To quantify the throughput benefits of alternative line configurations, we had to model two related aspects. First is the choice of line configuration – that is, the number of parallel lines and the number of stations in each line – that maximizes the production throughput per worker team. We call this the line-configuration problem (LCP). Once we determined the line configuration, we had to coordinate each line by effectively assigning the M processing tasks to the N workstations so as to balance workloads. We call this the line balancing problem (LBP). Clearly, LCP and LBP are interrelated.

Managerial Insights

The effects of line configuration: We compared the throughput of one-, two-, three-, and four-station lines. Our experiments revealed that shorter balanced lines yield higher system throughput than longer lines. When per-station processing-time variability increases, the throughput of the shorter lines decreases more slowly than the throughput of longer balanced lines. Thus, balanced shorter lines are more robust with respect to variability.

The effect of line balancing: To quantify the improvement in expected throughput resulting from use of dynamic line balancing, we compare the throughput of six two-station lines versus four three-station lines, under both static and dynamic line balancing. Dynamic line balancing may be more useful for balanced lines (same expected processing time per station) with high variability or unbalanced lines with low to mid variability.

Throughput Improvement at Visteon: The Big Surprise

Visteon management was interested in line reconfigurations that would improve throughput by more than 20%. Given the specific processing time variability at the R and P remanufacturing line at Lamosa, our study indicated that the firm could improve throughput by as much as 35% by converting to a single station assembly line.

Our study helped the firm in three ways. First, it provided managers with qualitative insights on line configuration. Second, it enabled Visteon to quantitatively assess the benefits of alternative configurations. Finally, it gave managers target performance levels (in terms of throughput) for benchmarking their reconfigured lines. Based on our recommendations, the plant managers have reconfigured the four station assembly line into four single-station lines. They are also considering a similar reconfiguration of the other remanufacturing lines at Visteon Lamosa. ❖

This article was excerpted and modified from: Kekre, Sunder; Rao, Uday; Swaminathan, Jayashankar and Zhang, Jun, "Reconfiguring a Remanufacturing Line at Visteon, Mexico," Interfaces, Vol. 33, No. 6, November-December 2003, pp. 30-43. Reprinted by permission. Copyright 2003, the Institute for Operations Research and the Management Sciences, 7240 Parkway Drive, Suite 310, Hanover, MD 21076 USA.

Remanufacturing Production vs. New Production

Remanufacturing products from recycled or recovered components (in Visteon's case, recovered gear "cores") may change the production process in a number of ways. At Visteon's plant, the differences include:

- *The quality of recovered cores is highly variable.*
- *Quantities of components are uncertain because consumption depends on the quality of the cores (good quality cores need fewer components replaced than old, worn-out cores). This uncertainty often precipitates a mismatch between supply and demand.*
- *Remanufacturing lines exhibit varying processing times in repair and finishing.*
- *Processing times are not known until the core is tested.*



UNC Kenan-Flagler is pleased to welcome two new faculty members whose teaching and research interests center on topics of sustainable enterprise. **Lisa Jones Christensen** and **Larry Chavis** will join the Kenan-Flagler faculty and begin teaching in the 2006-07 academic year. (See bios at right.)

The course **MBA 251B, Sustainable Enterprise**, will be offered in the “**custom core**” for the first time in 2006-07. First-year MBAs will have the opportunity to take the class as part of their core curriculum during Mod III.

CSE Consulting is heading into its second summer of work with a team of six rising 2nd year MBAs who are sure to impress. The 2006 CSE Consultants are: **Ruchira Baranwal, Tomoko Ito, Jim Hutton Johnson, Tzu-Chiang (John) Li, Jeffrey Mittelstadt, and Liliana Neceaeva.**

The Center for Sustainable Enterprise received a \$100,000 sponsored research grant from **Bank of America** to conduct an Environmental Footprint Assessment for the firm. The CSE is working in conjunction with the Carolina Environmental Program on this multi-disciplinary project which will assess the environmental impacts of Bank of America’s internal operations.

The CSE hosted the second annual **Graduation and End-of-Year Recognition Celebration** on April 18. Students, faculty and staff gathered to recognize the Class of 2006 MBA graduates who completed the Sustainable Enterprise concentration, the Net Impact club leaders, and the student teams who won case competitions. A great time was had by all!



Kenan-Flagler hosted the first annual **Sustainable Venture Capital Investment Competition** (SVCIC) on March 31-April 1. Created as a companion to UNC’s well-known global **VCIC** competition, this student-organized competition is the first of its kind. In it, teams act as socially-minded venture capitalists, evaluating entrepreneurs’ business plans and deciding which to invest in. MBA teams from the Northwestern (Kellogg), UC-Berkeley (Haas), Columbia Business School, Duke (Fuqua), and UNC (Kenan-Flagler) participated in competition’s first year.



Alumni Spotlight

Chris Strausz-Clark (MBA 2000)

A Senior Financial Analyst at the Bill and Melinda Gates Foundation, Chris is responsible for supporting the financial and business planning efforts of the Foundation’s Pacific Northwest and Global Libraries grant programs. Following a career at Sara Lee Corporation in South Africa, France and the U.S., Chris completed an MBA at UNC Kenan-Flagler and a Master of Public Policy at Duke. He credits the Kenan-Flagler sustainable enterprise program for helping him conceptualize sustainability beyond profit and constantly think about the big picture.



Sustainability is a primary criterion for grant making at the Bill and Melinda Gates Foundation. The organization constantly faces the challenge of not only identifying and funding programs that address deeply entrenched social problems, but also ensuring the sustainability of these programs. In evaluating funding opportunities, Chris and his colleagues attempt to define, forecast and marshal the resources required to implement and sustain the entire project, not just the Foundation’s portion.

... [more about Chris](#) ...

New Faculty Members Join UNC Kenan-Flagler



Larry Chavis
Assistant Professor

Larry’s research focuses on the challenges posed by weak institutions in developing countries for new business formation. His current projects include the study of how organizational design affects the delivery of development aid to rural communities and small-scale entrepreneurs in Indonesia. As a member of the Lumbee Tribe and a native of North Carolina, Professor Chavis has a strong interest in issues facing NC. Future projects include work on minority entrepreneurship, NC’s changing demographics and rural economic development. He holds a PhD in economics from Stanford; an MS in applied economics and management and an MA in Asian studies from Cornell; and a BA in anthropology from Duke.



Lisa Jones Christensen
Assistant Professor

Lisa’s research centers on leadership, commitment to change, and sustainable business in the U.S. and developing economies. Her latest research is an examination of social influence on commitment to change and implementation behaviors, which earned her an *Academy of Management* best paper award. She is passionate about finding ways to fight poverty through the private sector. This spring, she taught the MBA class “Innovation and Entrepreneurship in Developing Economies” as well as an undergraduate course in Sustainable Enterprise at UNC Kenan-Flagler. Her future projects include teaching sustainability in the MBA custom core. Lisa earned her PhD in organizational behavior from UNC Kenan-Flagler; her MBA and a Masters in International Development from Brigham Young Univ.; and her BA in English & History from UC-Berkeley.



CSE
ANNUAL CONFERENCE

REINVENTING TODAY'S BUSINESS

for the CHALLENGES of TOMORROW

The first **CSE annual conference** was held on March 30-31, 2006 in RTP, NC. **"Reinventing Today's Business for the Challenges of Tomorrow"**, featured presentations from thought leaders in academia and the corporate world about the latest research on and application of sustainable business practices.



Conference highlights included:

- Opening keynote by **Andrew Shapiro** from GreenOrder about the opportunities for strategic business advantages in sustainability initiatives
- Gala reception and dinner with evening keynote by thought leader **Janine Benyus**, author of *Biomimicry*, about looking to nature for innovative, simple and efficient product and process design
- Participation by 100 members of the corporate, nonprofit, government and academic communities across the country
- Presentation of sustainability concepts from both academic and practitioner perspectives
- UNC Kenan-Flagler students' publications and projects showcased at the gala reception

Some of the presentation topics included:

- CSR strategy and reporting and Ethics in a global context
- New markets for ecosystem services and brownfields redevelopment
- Social enterprise and social marketing opportunities
- Incorporating environmental management into business strategy
- Models of innovation and design
- Double bottom-line investing valuation

For a full agenda, visit the [conference website](#).



Student Spotlight

Elena Miller (MBA 2007)

Elena is a first-year MBA student and the newly elected president of the UNC Kenan-Flagler Net Impact Club. Her future goal is to be a key figure in leveraging the human and financial capital of the private sector to improve environmental and social conditions around the world. Most importantly, she hopes to be in a position where she can help prove that sustainability and profitability are no longer mutually exclusive corporate goals.



"Among all of the entities functioning in the world, private enterprise has the greatest access to financial resources and human creativity," she says. "The influence of business on governments and the public sector is undeniable, and only continues to grow as marketplaces become global. ... I believe it is vital for today's business people to consider the footprint of their business decisions on the global community."

This summer, Elena will be interning in Bangkok, Thailand, working to diagnose and solve the export logistics issues of small Thai businesses in their attempt to increase connectivity across Asia.

... [more about Elena](#) ...

UNC Teams Win National Student Competitions

1st Place Leeds/ Net Impact Case Competition



A team of UNC MBA students took first place at the prestigious 2006 Leeds/Net Impact Case Competition, placing UNC in the Top Three for three years in a row. This annual MBA competition focuses on the relationship between business decisions and societal impact. Twenty teams from the U.S. and Canada participated. Congratulations to the winning team (*l to r*): **Betsy Vos Reeves, Natacha Warner, Annie Lux, and Christina Benz** (all MBA 2007).

1st Place Global Citizenship Challenge



UNC MBAs took top honors at the Global Citizenship Challenge held at Thunderbird this spring. The winning team beat out more than 56 teams from around the world in this global MBA competition that focuses on corporate citizenship, sustainability, and international development. Congratulations to (*l to r*): **Kent Sears, Elena Miller, Jay Carlis, Jim Hutton Johnson and Jenny O'Connor** (all MBA 2007).

1st Place Sustainable Venture Capital Investment Competition



A UNC Kenan-Flagler team also won the first annual Sustainable Venture Capital Investment Competition, hosted by UNC (individuals and school names were disguised so judging was blind). Congratulations to (*l to r*): **David Cook, Allison Moy, Jonathan Owens, Erin Simons, and Jeff Mittelstadt** (all MBA 2007).



The *Financial Times* published an article by CSE Director **Al Segars** titled "Rewriting the Rules" as part of their "Mastering Uncertainty" series (Mar. 31). The article illustrates how sustainable business models require a shift in conventional wisdom.

Entrepreneurship professor and Director of the Urban Investment Strategies Center **Jim Johnson** and Kenan Institute Director **Jack Kasarda** co-authored a report of the first major comprehensive study of North Carolina's Hispanic population and its economic impact ([available for download](#)). The study was cited when ABC's "World News Tonight" interviewed **Jack Kasarda** in "The Impact of Illegal Immigrants." (Mar 30) and when *Time* quoted him in "What it means for Your Wallet" (Apr 10).



Marketing professors, **Paul Bloom** and **Steve Hoeffler** recently published the article, "How Social-Cause Marketing Affects Consumer Perceptions," with co-authors, Kevin L. Keller, and Carlos E. Basurto Meza in *MIT Sloan Management Review* (Vol. 47, No. 2, Winter 2006). Dr. Bloom presented this research at the 2006 CSE Conference in March.

Paul Bloom also presented "The Limitations of Better Nutritional Labels" at the American Marketing Association Educators' Conference in February 2006 in St. Petersburg Beach, Florida.

Lisa Jones Christensen will be presenting a paper she co-authored, "Introducing Microfinance and Bottom of the Pyramid Concepts into Business School Curricula" at the 13th Annual Greening of Industry Network conference, GIN 2006 in Cardiff, Wales July 2-5.

CSE Executive Director, **Katie Kross** was quoted in the November issue of *Business Leader* magazine in "[Sustainability: Business Practices to Meet the Challenges of the 21st Century.](#)"

Al Segars was recently appointed to the board of directors of [Sustainable North Carolina](#), a nonprofit that helps organizations realize the benefits of sustainable development practices.

Operations professor, **Jay Swaminathan** published "Managing New and Remanufactured Products" with former Kenan-Flagler faculty member, Gerardo Ferrer in *Management Science*. (January 2006).

The **Carolina Environmental Program (CEP)** received \$150,000 from Progress Energy to create the Center for Sustainable Energy, Environment and Economic Development at UNC. The **SEED Initiative** will focus on the ways society responds to growing needs for energy associated with economic development, while also improving the environment.

Lisa Jones Christensen will be given the best paper award in the organizational development and change division at the upcoming *Academy of Management* conference for her paper, "Social Influence Effects on Commitment to Change and Implementation Behaviors."

The **Kenan-Flagler community** was featured in *Financial Times* upon the dedication of a newly-built Habitat for Humanity home in Chapel Hill. The house was built by nearly 300 students, alumni, faculty and staff for the Shah family (Apr. 18)... [more](#)

The *New York Times* quoted CSE director, **Al Segars** in "[DuPont Looking to Displace Fossil Fuels as Building Blocks of Chemicals](#)" (Feb 28).

Sustainability in NC: Events

For more news, announcements & events related to sustainability and sustainable business in NC, visit:

[NC Sustainability Network](#)

Apr. 27-29

2nd Annual American Indian Business Summit & Expo
NC Indian Econ. Devt. Initiative
Raleigh, NC
[more info](#)

Apr. 28

U.S. Green Building Council
Triangle Chapter
Annual Membership Meeting
RTP, NC
[more info](#)

Apr. 30

Earth Action Fest
Carrboro, NC
[more info](#)

May 2

Speaker: Bill McKibben
"Climate Change as Moral Challenge: How Big Should We Be?"
Warren Wilson College
Asheville, NC
[more info](#)

May 9

Sustainable Business
Speed Networking Event
Triangle Net Impact
Durham, NC
[more info](#)

May 20-21

Durham Home Builders Green
Building Tour
Durham, NC
[more info](#)

Jun. 1

Conservation Development
Workshop with Randall Arendt
Winston-Salem, NC
[more info](#)

Jun. 6-7

Fuel Cell 2006 Conference
Raleigh, NC
[more info](#)

Jun. 14-16

NC Economic Developers Assn.
2006 Annual Conference
Asheville, NC
[more info](#)



Toyota, UPS, Nokia, and Bank of America are some of the firms named in Jan. to the [2006 Global Most 100 Sustainable Companies in the World](#).

Wal-Mart announced plans recently to purchase fish from [sustainable fisheries](#) and expand [organic products](#) in its retail stores.

In an industry first, **Ford** issued a [report addressing the business implications of climate change](#), carbon dioxide emissions and global energy concerns.

The non-profit group **Business & Human Rights Resource Centre** launched a [new subscription service](#) to alert companies to news about public perceptions of their social and environmental conduct.

In [Time magazine's Apr. 3 special report](#) on global warming (cover story: "Be Worried. Be Very Worried."), **Cinergy** and **Wal-Mart** were featured as forward-thinking companies on the issue of climate change.

Investors Circle and the **Skoll Foundation** will convene the "[Patient Capital for a Sustainable Future](#)" conference in San Francisco on May 10-12.

On May 8-9, the World Bank's **Development Marketplace** will showcase 118 cutting-edge finalist projects in a competition themed "[Innovations in Water, Sanitation and Energy Services for Poor People](#)."

Powered by Renewables Corp. and **SunEdison** plan to build an [18-megawatt photovoltaic plant](#) in Clark County, Nevada, the largest solar energy project of its kind.

Nedbank became the [first African bank](#) to adopt the Equator Principles.

Academics Robert Repetto and Daniel Dias propose a new financial **measure of environmental impact** dubbed "[TRUEVA](#)" that combines external environmental costs with economic value added (EVA) figures.

Cisco Systems, Grand Circle Corporation, and KaBOOM! / The Home Depot were recognized with "[Excellence in Corporate Philanthropy](#)" awards from the Committee to Encourage Corporate Philanthropy (CECP).

DaimlerChrysler introduced the world's [first fuel cell-powered police car](#) in Apr. In recent months, the firm has also delivered fuel cell buses to the [City of Beijing](#) and extended the [European fuel cell bus project](#).

Adobe Systems is realizing savings of \$1 million annually since adopting energy efficiency and [green building technologies](#) at its headquarters facility.

Nike and **Hewlett-Packard** were recognized in April for [Best Sustainability Reports](#) by the Ceres Coalition and Association of Chartered Certified Accountants (ACCA).

The **International Business Leaders Forum** and the UN World Tourism Organization announced the launch of a new joint [Tourism and Human Rights Initiative](#).

Entries are open for the 2006 **MetLife Foundation Awards for Excellence in Affordable Housing**. Deadline May 5.

7 World Trade Center, a 52-story building replacing one that fell at that address on 9/11 earned [LEED Gold certification](#) by the U.S. Green Building Council and featured in a [New York Times article](#) on green building.

Whole Foods made the largest ever [purchase of wind power](#) credits in the U.S. in January. The firm was also recognized as the largest retail purchase of renewable energy in the [EPA's Green Power Partnership](#).

Reading & Resources

[The Sustainability Yearbook 2006](#)

Research on sustainability trends and corporate sustainability performance from Sustainable Asset Management and PricewaterhouseCoopers.
(Apr. 2006)

[Clean Energy Trends 2006](#)

Survey of clean energy markets and investment opportunities by Clean Edge, Inc.
(Mar. 2006)

[2005 Report on Socially Responsible Investing Trends in the U.S.](#)

Summary of trends in socially responsible investing (SRI) over the past 10 years, prepared by Social Investment Forum.
(Jan. 2006)

[McKinsey Global Survey of Business Executives: Business & Society](#)

Survey of business executives' attitudes about corporate social responsibility and the role of business.
(Jan. 2006)

[Intangibles and CSR](#)

Business Brief by BSR Senior Advisor Allen White that explores the link between a company's intangible assets and corporate social responsibility (CSR).
(Feb. 2006)

[Pacific Sustainability Index](#)

Index developed by the Roberts Environmental Center (Claremont McKenna College) that rates companies' environmental/social performance and reporting. Corresponding publications include periodic [industry sector reports](#).