# Minimizing Material Content in Green Production Through Automation

**Kelly Weeks**
**Lamar University**

*This study considers the important concept of greening production. Focusing on a few distinct areas does this, all though automation. First, material usage is looked at. Reducing scrap and waste has always been of the upmost importance. Second, improving the amount of recycled content is analyzed. This is done primarily because of the shift if consumer beliefs. Consumers once thought recycled meant inferior quality, that mindset has not been all but left behind. Third, is the ultimate test of corporate success, profitability. To this effect, a large-scale study was conducted on public and private firms to give insight into these relationships.*

## INTRODUCTION

For a long time it has been well accepted that the inclusion of environmental concerns is important to corporate and business strategies (Bourgeois, 1980). Companies have slowly begun to recognize their responsibility in regard to environmental performance of themselves and their suppliers (Zhu et.al., 2010 Greening of production refers to the reduction of pollution causing substances such as solid and liquid wastes, air emissions, and noise (Purba, 2004). This "greening" also includes the conservation of renewable and non-renewable natural resources (Rao, 2003).

Purba (2004) tells that by expanding manufacturers responsibility, the companies then try and implement environmental aspects into the design of products, raw material choices, and technology. This concept is even generally expended to suppliers and business partners. Additionally, participation of workers in the firm is needed to make this greening a reality.

Environmentalism is becoming a standard demand of customers, shareholders and industry partners alike. This is especially true as it can provide a financial incentive as well as a social one. In the United States of America, various incentives are given at all levels of government to motivate companies to embrace green production. Therefore, an empirical analysis is not only useful, but needed.

## THEORETICAL BACKGROUND

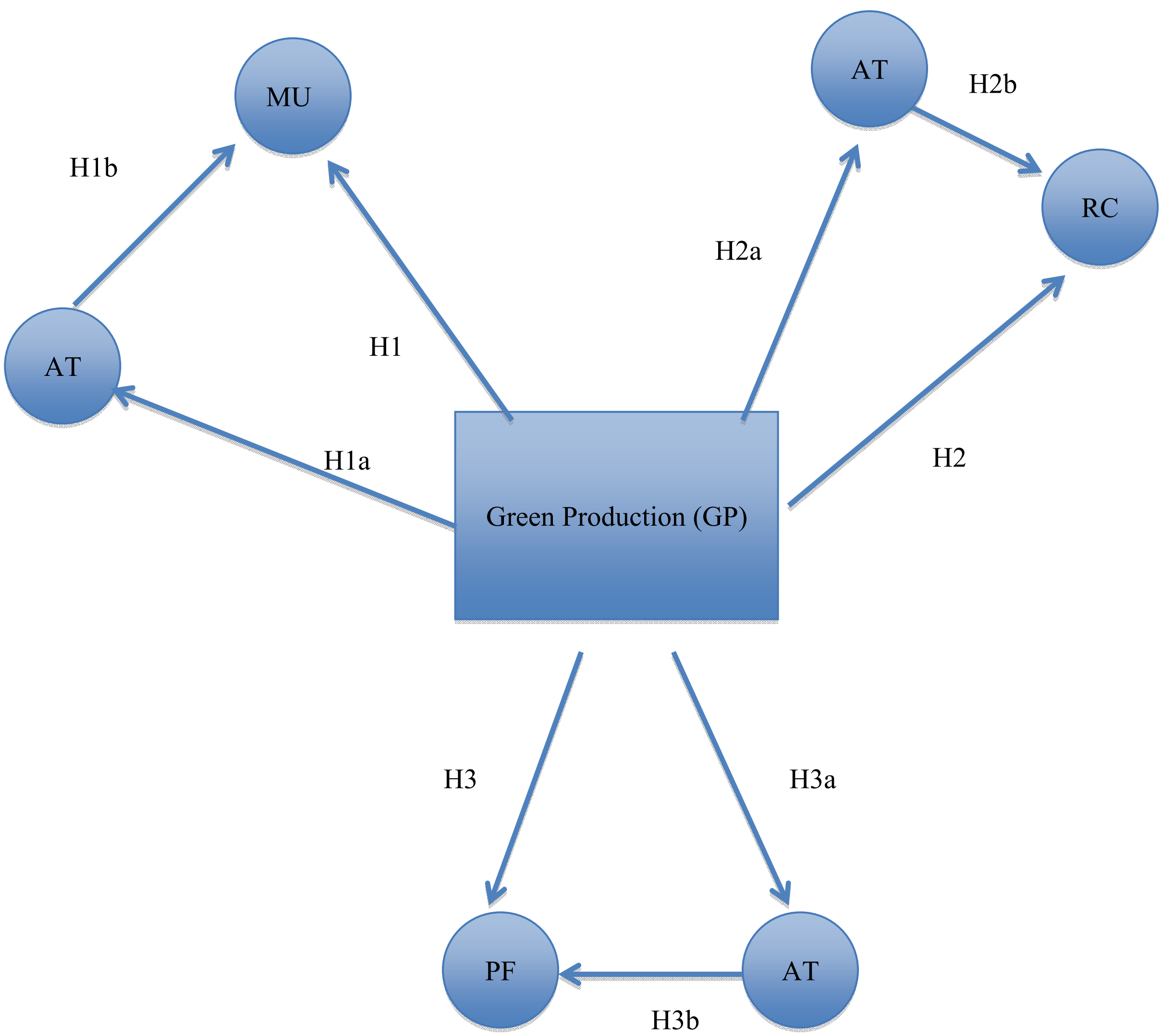
In logistics and operations literature, sustainability and environmental considerations are topics of increased interest. As more firms engage in efforts to reduce risks and improve the competitive situation of their firm this becomes increasingly important to consider (Perotti *et al.*, 2012; Dey *et al.*, 2011; Rao and Holt, 2005; Porter and van der Linde, 1995).

In recent years much theory has been written on environmental sustainability (Björklund and Forslund, 2013; Pazirandeh and Jafari, 2013; Carter and Rogers, 2008; Srivastava, 2007; Wu and Dunn, 1995). Internal environmental practices alone have been shown to be a necessary but not also a sufficient condition to improve the environmental impacts (De Giovanni, 2012). Therefore, it is vital to include all levels and layers of the supply chain in efforts of improvement. One such area is reducing the amount of material used in production, whether it is enabling lean management or reducing scrap and rework. This leads to:

**Hypothesis 1**: As green production automation levels increase, the amount of material usage per unit is reduced.

H1 is a direct route without use of automation means and the effect thereby on material usage. H1a and H1b add in the mediating variable of automation and its supposed improvements upon material usage.

**FIGURE 1**
**CONCEPTUAL MODEL OF THE RELATIONSHIPS AMONG MANIFEST VARIABLES**



AT= Automation
GP= Green Production
MU= Material Usage
RC= Recycled Content
PF= Profitability

Firms can increase their competitive advantage as a result of a stronger triple bottom line, (composed of social, economic, and environmental issues or people, planet, and profit) propositions are created from a natural-resource-based view of the firm perspective that is supported using accounting theory, management strategy, green logistics and supply chain literatures (Markley et.al., 2007). Other countries have begun realizing the importance of green logistics and energy (Jiang et.al., 2007). Recycled content plays an important role hence:

**Hypothesis 2**: As green production automation levels increase, the percent of recycled content in the product also increases.

H2 is a direct route without use of automation means and the effect thereby on recycled content. H2a and H2b add in the mediating variable of automation and its hypothetical improvement upon recycled content.

Rothschild (2006) tells that profit maximization is the primary goal of all firms regardless of what service or product they offer. Particular emphasis should be places on return on equity (ROE). Weeks (2010) notes that just important is a wholisitc approach where ROA, ROI, and net income are also incorporated into the analysis. Jaggi and Freedman (1992) support the use of ratios multiple ratios to analyze a firm's profitability. As profitability is so important:

**Hypothesis 3**: *As green production automation levels increase, profitability of the firm will increase.*

H3 is a direct route without use of automation means and the effect thereby on l profitability. H3a and H3b add in the mediating variable of automation and its presumed improvement upon profitability.

## METHODOLOGY AND ANALYSIS

### Questionnaire Design

A survey item was designed to obtain responses on a five-point Likert scale. A score of 1 represents very poor and 5 is excellent. Actual data is limited in this type field. This may be one reason more research in this area has not been previously done. Therefore, perceptions of observed or suspected benefits were asked. Surveys were mailed to a mid to upper level manager, so they would have the expertise and knowledge on which to draw upon for these type questions.

Questionnaires were emailed when possible. Remaining surveys were sent via United State Postal Service (USPS). Each questionnaire included a self-addressed, postage paid return envelope.

### Data Collection

Primary data collection methods were used. Data was collected from various types of industries located in the United States, Mexico and Canada using the survey instrument that was developed. These individual companies' emails addresses were collected through various means. However, all came via the Internet.

The combined population size is over one thousand companies. A total of 1000 surveys were mailed to various firms throughout the United States, Mexico and Canada. 167 surveys were returns. 7 of the 167 were found to be unusable. This brought the effective sample response rate to 16.0%. Appendix 1 and 2 show a profile of respondents as well as some brief demographic descriptors.

### Validity Statistics and Results

Confirmatory factor analysis (CFA) was used to test the latent variables. According to Hair et.al., (1998) CFA permits the indicators to load only on certain pre-selected factors, which proved important in this study.

Table 1 provides several goodness-of- fit statistics to judge how well the model explains the observed data from the aspects of: absolute fit, incremental fit, and parsimonious fit (Tanaka, 1993; Maruyama, 1998). The absolute fit measures of GFI, AGFI, and the Normed chi-square indicate a good fit of the model to the data (Bentler and Bonnet, 1980; Bagozzi and Yi, 1988).

Within Table 1, three incremental fit indices are mentioned. Normed Fit Index (NFI) represents the proportion of total covariance among observed variables explained by a target model using a baseline null model (Devaraj et al., 2012). Incremental Fit Index (IFI) is a ratio of the discrepancy of the proposed and baseline models over the difference of their respective degrees of freedom (Bollen, 1989). Comparative Fit Index (CFI) governs incremental fits and approximates non-centrality parameters of the model (Gefen et al., 2000). Validity statistics in Table 1 provide convincing evidence of good model fit.

**TABLE 1**
**VALIDITY STATISTICS**

| Goodness of fit indices | |
|---|---|
| Absolute fit | |
| Normed Chi-square | 1.2650 |
| Goodness of Fit Index (GFI) | 0.9350 |
| Adjusted Goodness of Fit Index (AGFI) | 0.9170 |
| Incremental Fit | |
| Normed Fit Index (NFI) | 0.9185 |
| Incremental Fit Index (IFI) | 0.9190 |
| Comparative Fit Index (CFI) | 0.9175 |
| Parsimonious Fit | |
| Root Mean Square Error of Approximation (RMSEA) | 0.0525 |

Within Table 1, three incremental fit indices are mentioned. Normed Fit Index (NFI) represents the proportion of total covariance among observed variables explained by a target model using a baseline null model (Devaraj et al., 2012). Incremental Fit Index (IFI) is a ratio of the discrepancy of the proposed and baseline models over the difference of their respective degrees of freedom (Bollen, 1989). Comparative Fit Index (CFI) governs incremental fits and approximates non-centrality parameters of the model (Gefen et al., 2000). Validity statistics in Table 1 provide convincing evidence of good model fit.

A summary of the hypotheses test results, performed using IBM SPSS 21, is presented in Table 2. The results of the analysis provide support for H1-H3.

**TABLE 2**
**STATISTICAL MODEL**

| LISREL Parameter | Hypothesis | Standard Error (S.E.) | Critical Ratio | Standardized regression weights | P-value | Supported |
|---|---|---|---|---|---|---|
| AT>MU | H1 | .024 | 4.546 | 0.393 | .000 | Yes |
| AT>RC | H2 | .014 | 3.658 | 0.427 | .000 | Yes |
| AT>PF | H3 | .036 | 4.162 | 0.415 | .000 | Yes |

## FUTURE RESEARCH & IMPLICATIONS

Supplementary paths of thought are many. New research may choose to address empirical inadequacies in areas of product redesign to ensure green compliance, process optimization or evaluation the amount of money spent per unit of energy to name a few. Future research in green areas in not limited. In fact, just the opposite, it is exploding as companies are eagerly exploring all avenues of its advantages.

Additionally, it is hoped that this research will re-ignite the importance of automation in a manufacturing setting. Automation has been viewed in many negative lights in the media but as this research shows it provides a useful benefit at both a social and economic level.

## CONCLUSIONS

The context of energy and the environment is ever changing. Part of this is due to social responsibility, but part of this is due to threats of disruption. Companies do not wish to be at the mercy of power companies, Mother Nature, or for that matter terrorists. This research has shown clear evidence of the importance to firms combining green methods with automation. It is not just fashionable anymore to be green. Now it is also profitable.

## REFERENCES


Bagozzi, R. P., & Yi, Y. (1988). On the evaluation of structural equation models. Academy of Marketing Science Journal, 16(1), 74-94.

Bentler, P.M., & Bonnet, D.G. (1980). Significance tests and goodness of fit in the analysis of covariant structures. Psychological Bulletin, 88(3), 588–606.

Björklund, M. and Forslund, H. (2013), "The purpose and focus of environmental performance measurement systems in logistics", International Journal of Productivity and Performance Management, Vol. 62 No. 3, pp. 230-249.

Bourgeois, L.J. (1980), "Strategy and environment: a conceptual integration", Academy of Management Review, Vol. 5 No. 1, pp. 25-39.

Carter, C.R. and Rogers, D.S. (2008), "A framework of sustainable supply chain management: moving toward new theory", International Journal of Physical Distribution & Logistics Management, Vol. 38 No. 5, pp. 360-387.

De Giovanni, P. (2012), "Do internal and external supply chain environmental management perform the triple bottom line?", International Journal of Operations and Production Management, Vol. 32 No. 3, pp. 265-290.

Dey, A., LaGuardia, P. and Srinivasan, M. (2011), "Building sustainability in logistics operations: a research agenda", Management Research Review, Vol. 34 No. 11, pp. 1237-1259.

Gefen, D., Straub, D.W., & Boudreau, M.C. (2000). Structural equation modeling and regression: guidelines for research practice. Communications of AIS, 4 (7), 71–78.

Hair, J., J.F., Anderson, R.E., Tatham, R.L., & Black, W.C. (1998). Multivariate Data Analysis. Upper Saddle River, NJ, Prentice Hall.

Jaggi, B., & Freedman, M.B., 1992. An examination of the impact of pollution performance on economic and market performance: pulp and paper firms. *Journal of Business Finance & Accounting,* 19(5), 697-713.

Jiang, Kejun, Zhu, Songli, Shrestha, Ram M.(2007). Analysis of policy options for promotion of clean and energy efficient technologies in the transport sector in Beijing. International Journal of Environment & Pollution. Vol. 30, Iss. 1; pg. 59.

*Markley, Melissa J., Davis, Lenita (2007).* Exploring future competitive advantage through sustainable supply chains. International Journal of Physical Distribution & Logistics Management. Vol. 37, Iss. 9; pg. 763.

Maruyama, G.M., (1998). Basics of Structural Equation Modeling. Sage Publishers, Thousand Oaks,

CA.
Pazirandeh, A., & Jafari, H. (2013). Making sense of green logistics. International Journal of Productivity and Performance Management, 62(8), 889-904.
Perotti, S., Zorzini, M., Cagno, E. and Micheli, G.J.L. ( 2012 ). " Green supply chain practices and company performance: the case of 3PLs in Italy ", International Journal of Physical Distribution & Logistics Management, Vol. 42 No. 7, pp. 640 - 672 .
Porter, M.E. and van der Linde, C. (1995), "Toward a new conception of the environment-competitiveness relationship", Journal of Economic Perspectives, Vol. 9 No. 4, pp. 97-118.
Rao, P. and Holt, D. (2005), "Do green supply chains lead to competitiveness and economic performance?", International Journal of Operations & Production Management, Vol. 25 No. 9, pp. 898-916.
Rao, P. (2004). Greening production: A south-east asian experience. *International Journal of Operations & Production Management, 24*(3), 289-320.
Rothschild, M., 2006. Shareholders pay for ROA. *Strategic Finance,* 88 (5), 26-32.
Srivastava, S.K. (2007), "Green supply chain management, a state of the art literature review", International Journal of Management Reviews, Vol. 9 No. 1, pp. 53-80.
Tanaka, J.S. (1993). Multifaceted conceptions of fit in structural equation models. In: Bollen, K.A., Long, J.S. (Eds.), Testing Structural Equation Models. Sage Publishers, Newbury Park, CA.
Weeks, K., Gao, H., Alidaeec, B., & Rana, D. S. (2010). An empirical study of impacts of production mix, product route efficiencies on operations performance and profitability: A reverse logistics approach. *International Journal of Production Research, 48*(4), 1087.
Wu, H.-J. and Dunn, S.C. (1995), "Environmentally responsible logistics systems", International Journal of Physical Distribution & Logistics Management, Vol. 25 No. 2, pp. 20-38.
Zhu, Q., Dou, Y., & Sarkis, J. (2010). A portfolio-based analysis for green supplier management using the analytical network process. *Supply Chain Management, 15*(4), 306-319.

## Appendix 1: Respondent Characteristics

| Position | % of respondents | Years Experience | % of respondents | Age Group | % of respondents | Highest Education Level Completed | % of respondents |
|---|---|---|---|---|---|---|---|
| Upper Management | 21.14 | <5 years | 10.48 | <30 years | 2.98 | High School | 6.47 |
| Mid Management | 50.90 | 6-10 years | 36.56 | 30-39 years | 3.23 | Associates | 9.95 |
| Other | 24.37 | 11-15 years | 31.84 | 40-49 years | 42.29 | Bachelor | 52.74 |
| No response | 3.48 | 16-20 years | 10.19 | 50-59 years | 25.87 | Graduate | 18.66 |
| | | >21 years | 3.98 | >60 years | 15.42 | Post Graduate | 2.99 |
| | | No response | 6.96 | No response | 10.20 | Other | 1.74 |
| | | | | | | No response | 7.46 |

## Appendix 2: Demographic profile of responding companies

| Size of Company base on labor force | % of respondents | Size of Company base on market capital | % of respondents | Region of Responding Company | % of respondents | Company Public or Private | % of respondents |
|---|---|---|---|---|---|---|---|
| <50 | 48.26 | >$1M | 12.69 | Northeast | 13.93 | Public | 12.19 |
| 50-100 | 32.83 | $1-5M | 70.90 | Northwest | 12.19 | Private | 77.61 |
| 100-200 | 15.67 | $5-10M | 10.20 | Central | 14.43 | No response | 10.19 |
| 200-500 | 1.49 | $10-25M | 1.49 | Southwest | 14.93 | | |
| >500 | 0.25 | $25-100M | 0.25 | Southeast | 12.69 | | |
| No response | 1.49 | >$100M | 0.00 | Canada | 31.34 | | |
| | | No response | 4.48 | No response | 0.50 | | |