Steelcase Green Product Development:
An Early Stage Life Cycle Analysis Tool and Methodology

By:

Caroline Conway

A project submitted in partial fulfillment of requirements
for the degree of Master of Science
(Natural Resources and Environment)

University of Michigan
Ann Arbor
April 15, 2008

Faculty Advisors:
Associate Professor Gregory A. Keoleian, University of Michigan
Acting Assistant Professor Michael Lepech, Stanford University

A report of the Center for Sustainable Systems

Report No. CSS08-01

Document Description

STEELCASE GREEN PRODUCT DEVELOPMENT:
AN EARLY STAGE LIFE CYCLE ANALYSIS TOOL AND METHODOLOGY
Caroline Conway
Center for Sustainable Systems, Report No. CSS08-01
University of Michigan, Ann Arbor, Michigan
April 15, 2007
231 pp., 29 tables, 33 figures, 12 appendices

This document is available online at: http://css.snre.umich.edu

Center for Sustainable Systems
School of Natural Resources and Environment
University of Michigan
440 Church Street, Dana Building
Ann Arbor, MI 48109-1041
Phone: 734-764-1412
Fax: 734-647-5841
Email: css.info@umich.edu
Web: http://css.snre.umich.edu

Abstract

Steelcase, Inc., a U.S. based and globally operating furniture company, has a long history of environmental improvement throughout its processes and products. Because its products are the core source of these impacts, integrating environmental metrics into the product development process has become a critical effort at the company.

Evaluating the environmental impacts of products can be challenging. Products are typically evaluated through a life cycle analysis (LCA) after design is complete. While this analysis is critical for public reporting and informing future products, a product cannot be revisited to improve performance once it is ready for production. Instead, evaluation of impacts needs to be an integral part of the product development process when materials, processes, and design options can be selected based in part on their expected environmental performance.

This research looked at the feasibility of using a data-driven environmental analysis tool, with the working title of Wizard for Environmental Life Cycle Evaluation (WELE), to reduce the time required for environmental decision making during product development and to minimize the uncertainty of evaluation results when a product design is incomplete. Based on discussions with Steelcase representatives, a beta version of the tool was created within an existing LCA software package and tested with Steelcase product developers to determine its usability. Additional research explored the integration of Steelcase-specific evaluation methods and product data needed to increase the tool's accuracy in reporting environmental impacts.

Several iterations of the tool were developed and tested with Steelcase representatives in Grand Rapids, Michigan and Strasbourg, France as well as IDEO, an affiliated product design consulting firm. Separate product tests were also conducted using completed LCAs for existing Steelcase products. These tests included evaluation of the impacts on full product performance when generic versus company-specific materials and processes were used. They also included modeling of the products in increasing detail to determine potential levels of reporting accuracy at each stage of product development.

This research indicated that there is value in using a data-driven approach to environmental analysis in early stage product development, but there are also several challenges. The product tests demonstrated that representative estimates of environmental impacts can be achieved in the early stages of product development, even when multiple design decisions remain to be made. Across the tests, environmental impacts represented at each stage of product development were compared with the products' final LCA results. In the concept phase of development, 18 (or 32% with a modified product) – 63% of final impacts were represented. This moved up to 50 – 80% of impacts represented in the design phase, 62 – 92% represented in the engineering phase, and 95 – 99% represented in the final production phase. While these results were promising, several challenges also emerged regarding the tool's usability as well as long term data collection and management. Therefore, while the data-driven approach has many benefits, improvements to the non-expert usability of LCA platforms and development of data collection efforts will be essential to optimize such an approach.

Acknowledgements

This research was made possible through funding from Steelcase, Inc. and support from the Center for Sustainable Systems at the University of Michigan's School of Natural Resources and Environment. Multiple people at Steelcase and the Center as well as representatives from IDEO, PRé Consultants, and EarthShift provided valuable guidance throughout this research. I would not have been able to complete this project without their insights and thank everyone who contributed to this project.

Denise VanValkenburg and Angela Nahikian at Steelcase were instrumental in presenting and developing the fundamental concept of an early stage data-driven development tool and provided critical financial support for the project. Denise was an essential resource in making connections with product development teams and others at Steelcase, IDEO, EarthShift, and PRé Consultants who in turn provided essential input throughout the project. Without Denise's help in synthesizing feedback from different groups and sharing the bigger picture of the tool's purpose at Steelcase, this research could not have been completed.

Greg Keoleian, Co-Director of the Center for Sustainable Systems, provided significant expertise in the development and implementation of this research. He has also acted as a mentor during my time at the University of Michigan, and his support of my professional and educational goals were primary reasons I chose to pursue my degree at the School of Natural Resources and Environment. I greatly appreciate having the opportunity to work with him throughout this educational experience.

Mike Lepech, Research Fellow at the Center for Sustainable Systems, was also instrumental in his guidance and commitment to this project. It was with Mike's help that I was able to address many of the more challenging and detailed aspects of this research. He provided a level of technical expertise that was critical not only to the success of the project but to my personal education about life cycle analysis and other elements of environmental assessment.

Many others at Steelcase, the Center for Sustainable Systems, IDEO, PRé Consultants, and EarthShift contributed to this research in ways far too many to mention. This breadth of feedback, insight, and support was essential in bringing the project to the point it has reached. I sincerely thank everyone who provided their time and expertise over the course of this research.

Table of Contents

List of Tables

List of Figures

1.0 Description of Research

1.1 Introduction

In the process of developing and manufacturing consumer products, industrial companies are responsible for significant environmental impacts. These impacts include contributions to climate change, local and regional air pollution, human- and eco-toxicity, and resource consumption. The intermediate sources of these impacts are equally broad, including energy use and other inputs to production, material extraction and processing, transportation between facilities and customers, and the use and disposal of products after delivery to customers.

While these sources of impacts are tied directly to the process of manufacturing products, many of the decisions that lead to their implementation are made during product design and development. Industrial companies that face increasing demands to mitigate their effects on the environment are beginning to look at the tie between early stage product development decisions and final environmental impacts. Some companies are moving beyond plant, process, and waste stream improvements to address impacts as early as possible. These efforts are discussed in Section 2.5.

Steelcase, a U.S. based and internationally operating furniture company, is one of the industrial companies at the forefront of this trend. Having introduced environmental metrics and review procedures into various reviews during product development, the company is now seeking to integrate detailed and accurate environmental assessments into design and engineering decisions.

This proposition faces many challenges. Accurately estimating environmental impacts can be exceedingly difficult before a product is fully designed and its methods of production have been determined. The time required to evaluate environmental impacts can also be significant, and environmental decision making must fit into a set of product developer responsibilities that already includes multiple considerations.

To ensure accurate impact assessments and minimize the time required to produce these assessments, a tool is needed to integrate data on the environmental impacts of multiple materials, processes, and other inputs. This tool must also offer an interface that allows product developers to perform quick and relatively accurate assessments of these impacts when they are combined in a product concept. These needs serve as the basis for research into the development and testing of a tool for Steelcase product developers that incorporates data from multiple sources and provides reports on the environmental metrics and assessment frameworks most critical to product development.

1.2 Project Description

Steelcase approached the Center for Sustainable Systems (CSS) at the University of Michigan to assist its environmental group in developing and evaluating a tool for environmental decision making in early stage product development. This tool, with the working title of Wizard for Environmental Life Cycle Evaluation (WELE), was developed and tested with product developers over a one year period. Additional research covered the integration of Steelcase's environmental assessment frameworks into WELE and recommending an approach to data collection and management.

The objective of WELE and the supplemental research was to provide product developers with a manageable way to assess potential product impacts in multiple environmental areas. Such assessments need to be based on accurate environmental impact data for materials, processes, and other input factors, as well as on the interaction of these impacts in a product assembly. WELE is further intended to be usable at any stage of the product development process, which ranges from concept design to preparation for sourcing and production. Finally, the tool is intended to support the use of existing environmental targets in assessing products' environmental performance. This combination of a usable interface and accurate, relevant information will help developers make clear decisions about product designs based on environmental impacts.

1.3 Goals and Significance

To achieve the overarching objective of creating and evaluating a usable, relevant environmental assessment tool, several subordinate goals were identified:

- Identifying product development stages and the need for information at each stage that frame the approach to environmental assessment.
- Selecting a platform to manage large amounts of data and provide a usable interface.
- Maximizing usability and reporting functionality within the platform.
- Determining data collection and management methods that can feasibly be integrated into current company systems and responsibilities.
- Verifying the accuracy of estimated environmental impacts in early stages of product development through case studies based on existing products.

The significance of this research lies in its exploration of data driven assessment of environmental impacts in early stages of product development. The majority of information on early stage approaches to environmental assessment (discussed in Section 2.5) indicates that many companies rely on general policies and metrics that are usable but do not necessarily encourage comprehensive environmental assessment and decision making. If a data driven approach can also be usable, it will provide comprehensive information and help developers accurately identify preferable environmental options.

1.4 Approach

Development of WELE and supplemental research is divided into four major activities:

1. **Tool Development:** Platform selection, determination of an analytical approach to assessment, and construction of an interface for developers.
2. **Reporting:** Integration of existing assessment frameworks and metrics in WELE.
3. **Data Development:** Analysis of areas in which company-specific data is needed and can be integrated into WELE.
4. **Case Studies:** Tests of WELE using environmental assessments of completed products to determine the value of using company-specific data and the accuracy of results at different stages of product development.

WELE's structure (Section 3.0) was developed with input from product developers and environmental specialists at Steelcase's Grand Rapids headquarters, environmental experts working with product development teams in Steelcase's European offices, and product developers from the design consulting firm IDEO[1]. Additional input was provided by PRé Consultants, the developers and managers of the SimaPro platform used as the foundation for WELE, and EarthShift, distributors of SimaPro in the U.S.

Reviews of WELE were held at a number of points to collect feedback from each group. To the greatest extent possible, feedback was addressed in subsequent versions of WELE. Areas that could not be addressed within the platform were shared with PRé Consultants for use in longer term improvements to SimaPro.

Reporting (Section 4.0) and data inputs (Section 5.0) were treated as independent inputs to the WELE interface based on SimaPro's separation of data inputs from the creation of product evaluations. Approaches to the integration of reporting and data were explored in parallel with WELE's structural development.

Once WELE reached a functional point of development, case studies (Section 6.0) were conducted using existing Life Cycle Analyses (LCAs) of three Steelcase products. These case studies were the basis for testing the impact of generic versus company-specific data inputs as well as the accuracy of evaluations at each stage of product development.

A final version of the tool has been developed for use by Steelcase. While additional efforts are needed to establish data inputs and improve usability, WELE is functionally usable by product development teams. It is expected that information in support of further usability and accuracy improvements will result from user feedback over time.

---

[1] As of this writing, Steelcase had a minority investment in IDEO and this relationship generated interest in expanding the tool's use beyond Steelcase's formal boundaries.

1.5 Boundaries

Several boundaries distinguish this research from other environmental initiatives at Steelcase. The company has multiple existing efforts to improve environmental performance and discloses public information on its products' performance in selected cases. This research is not meant to extend to areas like environmental target establishment, operational improvements, and public reporting through Environmental Product Declarations (EPDs)[2]; rather, it is specifically focused on internal assessments during product development.

The distinction between internal and external reporting is particularly critical. An LCA that is used for public reporting must be conducted according to rigorous ISO standards[3], particularly if the data is to be used for a comparative assertion[4]. From an early point in this research, it was clear that externally reportable assessments would not be feasible without the full details of completed products and without the investment of environmental experts in conducting external reviews. Because WELE is intended to help non-experts participate in the life cycle analysis of product impacts, it incorporates relevant assessment frameworks and data but is not intended to produce full LCAs that meet ISO criteria for development, analysis, and review. At most, the results of a product analysis in the final stages of development can be used as the initial basis for an ISO 14040 compliant evaluation, minimizing the time required to collect data on product components, materials and processes.

The tool is also limited to use in product development rather than extending to broader corporate impacts, such as those addressed by plant managers and corporate strategy and policy groups. It focuses on the impacts of single products rather than assessing plant level operations or corporate footprint impacts which would be addressed by plant managers or strategists in response to external and internal policy goals. WELE does rely on policies and targets set by Steelcase's environmental strategy group, as

---

[2] A sample EPD for Steelcase's Think Chair can be found at: www.steelcase.com/na/files/dyn/3efc64a6dce742e6bbf8e818ef676326/04-0012421.pdf. Last accessed April 2008.

[3] These requirements are covered in detail in the International Standards Organization (ISO) Standard 14040. In addition to requirements for comparative assertions, as discussed above, the standard establishes requirements for inventory analysis, impact assessment, and life cycle interpretation as well as fundamental boundary, assumption, and data requirements. In the interest of encouraging LCA activity by non-experts, decisions on many of these points do not need to be made by users of the Steelcase tool. Rather, they are built into the tool to the greatest extent possible to maximize accuracy while retaining simplicity.

[4] According to ISO 14040, a "comparative assertion" is a public release of LCA information for the purpose of comparing a product's environmental performance to another. LCAs developed for this purpose must adhere to strict standards on data quality and be vetted through a critical review process before being released. Steelcase releases such LCAs, but they are developed by internal experts and are not expected to be the responsibility of product development teams. The environmental analyses conducted during product development are also not expected to replace these final LCAs, though they may be used as sources of data.

discussed in Section 4.0. While work was performed to integrate the policies into the tool structure, no alterations to metrics or policies were included in this research.

Because WELE is designed for early stage assessment of life cycle impacts, certain aspects of full LCAs are treated as inherent parts of the tool rather than decision making points for product developers. For example, the functional unit and system boundaries, often problematic in LCAs, are given minimal treatment in the tool's interface with users. This is feasible because each product development team will typically focus on a single product and make comparisons between iterations of the product rather than with other products or systems[5]. In addition, Steelcase's furniture products typically do not produce significant impacts during use, reducing the risk of inaccurate comparisons between short and long lived products[6].

---

[5] For example, a comparison between two different types of chairs requires careful identification of the functional unit (e.g. "provision of seating for X years") and the boundaries of analysis (e.g. whether end of life is included in calculations of each chair's environmental impacts). During the development phase at Steelcase, the functional unit for a product is defined early on as part of a marketing evaluation and conceptual design development. Therefore, by the time developers are evaluating different options for a product, they are already comparing these options within a consistent definition of the functional unit. The boundary issue is defined within the tool so that every product is evaluated within the same boundaries of pre-defined material profiles to represent early extraction and processing, more detailed profiles for immediate suppliers and internal Steelcase operations, and standard end of life profiles that can be applied consistently across products.

[6] The exception to the use phase exclusion is Steelcase's lighting products, which cause some use phase impacts through electricity consumption. However, these products, like others, will be compared based on iterations of a single product rather than across product lines. In the event that inter-product comparisons must be made, the tool does incorporate an option to establish use phase electricity consumption as part of a product profile. The definition of functional units early in development also minimizes the risk that a short lived product would be compared with a long lived one; the necessary life span of each product is defined through market analysis and early conceptual design.

2.0 Product Development and Environmental Contexts

This research is built upon Steelcase's product development process and existing methods for environmental analysis. Product development, particularly at large industrial companies, generally follows a standard, iterative path in which a product moves from concept through engineering to final production. Environmental analysis of products after development also follows a standard process. However, integrating the latter task into the former is not standardized, and companies may take very different approaches to this integration.

2.1 Industrial Product Development

Industrial product development follows an iterative process involving multiple participants in the development and review of the product in progress. Because this research is focused on Steelcase's process and needs, their general approach to product development is discussed below.

2.1.1 Phases

Like many industrial companies, Steelcase uses a stage-gate development process in which each product is partially developed and then reviewed before it is developed further. On a high level, the stages are described in Table 1.

Table 1 Product Development Stages

Stage	Purpose and Activities[7]
Concept	The feasibility of a product concept is explored based on market research, material and engineering explorations.
Design	A concept with potential for further development is moved into design where several functional product options are developed and evaluated. Material and structural decisions are made for each option.
Engineering	The design option that best meets cost, market potential, and other requirements is developed in greater detail with material, structural, and some process decisions made to bring the design to full functionality.
Process	The engineered product is completed and process / supply chain decisions are made to initiate production.
Reporting	In some cases, reporting on the development process is conducted to provide lessons learned for future products. Public reporting on environmental performance is also conducted at this point – i.e. when the product is fully developed.

---

[7] Discussions with Steelcase product development representatives.

2.1.2 Stage-Gate Reviews

After each of the stages of development shown in Table 1, a stage-gate review is conducted in which multiple groups evaluate the product and approve it for further development[8]. Factors considered in these reviews include the product's ability to meet market needs, functional requirements, cost targets, and manufacturing feasibility.

At Steelcase, environmental reviews have been introduced to the stage-gate process over time, and these reviews now take place at several points[9]. The goal of these reviews is to ensure that a product meets high-level environmental targets set for all products and, in some cases, specific environmental goals for the individual product. While WELE is intended to be used during product development itself, it serves a critical function in helping development teams identify impacts in preparation for these reviews.

2.1.3 Participants

The parties involved in development are diverse. Industrial designers and marketers are typically involved in the first concept stage. Engineers and product designers lead the design phase and engineers take primary responsibility for development in the engineering phase. In the production phase, many more functions are included, such as production planning, operations, and sourcing. At the stage-gate reviews, financial, marketing, operations, and environmental evaluators join the other functions in evaluating and approving the product in development.

Throughout all the stages, a product will often be overseen by a single product management team that coordinates with the other functions, oversees development, and transitions the product between stages. This is particularly critical in ensuring use of the WELE tool throughout development, as evaluation of the product's environmental impacts also needs to be coordinated over the course of all the stages.

2.1.4 Development Timeframes

The amount of time required to introduce a new product can vary widely by industry and company. At Steelcase, development typically occurs over a one year period or less, with some products developed in six month timeframes depending on their technical requirements[10]. An additional consideration is the number of simultaneous product introductions. At Steelcase and other furniture companies, new introductions occur frequently, resulting in concurrent product development efforts managed by multiple teams at any given time.

---

[8] Discussions with Steelcase product development representatives.

[9] Discussions with Steelcase environmental representatives.

[10] Discussions with Steelcase product development representatives.

2.1.5 Redesigns

New product concepts move through all the phases of development in Table 1. However, a more frequent activity is the redesign of existing products to meet changing market, functional, cost, or other requirements[11]. Such redesigns do not require revisiting all phases of product development and can potentially be completed through the third and fourth stages of engineering and process preparation alone.

This presents an upside and downside for improving product environmental performance. The redesign process involves a smaller team of participants and an existing product, so improvements can be made more rapidly with greater certainty. However, the potential for significant environmental performance improvements is limited because major material and process changes themselves are limited in a redesign. WELE's goal of being usable at each development stage allows redesigns to be evaluated in the same way as new products, but it cannot address the limitations on major environmental improvements through the redesign of products.

2.2 Environmental Impacts of Industrial Production

Production, use, and disposal of industrial products have a variety of environmental impacts. Throughout manufacturing and often during customer use of products, consumption of energy, as well as some chemical and material emissions, creates greenhouse gas emissions and air pollutants that contribute to climate change, air pollution, and acidification. Material and product processing often results in emissions impacting water quality, and water consumption for processing can also be significant. A wide range of air, water, and soil emissions throughout production can lead directly or indirectly to human and ecosystem toxicity. And the consumption of materials and energy to create products, as well as the way products are disposed of after customer use, affects natural resource availability and quality.

The specific impacts range across industries, but industrial environmental impacts as a whole have risen in every environmental impact category since mass industrial production began. Use of energy in industrial production was the source of 23.6% of total U.S. energy consumption in 1999[12]. The consumption of water in non-agricultural industrial production was 10% of the total in the same year[13]. Total consumption of raw materials for industrial production of products and buildings has risen dramatically over the past century, reaching more than 500 million megatons per year, compared to 200 million megatons at the start of the 20th century[14].

---

[11] Discussions with Steelcase product development representatives.

[12] Graedel, Thomas and Howard-Grenville, Jennifer. *Greening the Industrial Facility*. Springer Science and Business Media, Inc. 2005. Page 14.

[13] Ibid. Page 15.

[14] Ibid. Page 16.

The use and disposal of products at the end of their useful lives introduce a host of additional issues. When products are in use, their energy and water needs can play a role in climate change, air pollution, water availability, and water contamination. In some cases, degradation of products over the course of their useful life can contribute to human and eco-toxicity through the offgassing of chemicals. The disposal of products often has direct environmental impacts but also plays a primary role in natural resource degradation and depletion. The degree to which products or their materials and components can be reused and/or recycled is critical to the minimization of these impacts on natural resources from raw material extraction and processing.

Furniture manufacturers and other product assemblers play a central role in determining these impacts. While many impacts occur upstream during material extraction and processing, assemblers are responsible for selecting and processing these materials into final products. This gives them particular leverage in determining the total environmental impacts of products. Likewise, these companies are closest to the customer and are therefore often responsible for minimizing the impacts of use through the design of their products. In some cases, taking back products for remanufacturing or recycling also falls to these companies rather than their upstream suppliers. For example, European regulations now require some types of manufacturers to take back their products at the end of product life and mange the process of reuse and disposal.

These companies, particularly those producing consumer durable and household goods, face further challenges in mitigating environmental impacts due to the variety of products they manufacture and the complexity of inputs and processes that result from this variety. Steelcase's operations are indicative of this challenge. The company's products use a wide variety of metals, woods, plastics, textiles, and other materials depending on design requirements. Processing and packaging options can also vary from product to product. Therefore, environmental impacts can be completely different for a wood-based versus a metal-based piece of furniture due to different material inputs and processing requirements.

During use, furniture generally faces different challenges than other durable goods (such as appliances and transportation products) in terms of energy and water consumption. With the exception of lighting, furniture consumes essentially no energy or other resources during use. At the same time, the issues of offgassing and product lifespan remain critical elements in furniture's life cycle environmental impacts.

At the point of disposal, furniture presents similar opportunities for remanufacturing and recycling as other large durable goods. However, the implementation of such product and material reuse faces difficulties across industries, in part due to the limitations of existing recycling infrastructure in the U.S. and other regions. Successful remanufacturing therefore relies on systems to ensure the return of products rather than disposal as well as the design of products for disassembly and reuse.

The wide-ranging impacts of furniture products in different environmental impact categories are therefore largely driven by material inputs and processing, at least to a greater degree than durable goods with energy or water intensive use phases. This particular focus feeds into the development of WELE, with the tool primarily focused on material and process selection within product assembles and with later stages of the life cycle largely dealt with through standard profiles.

2.3 Industrial Ecology

Industrial ecology is the systematic evaluation and improvement of industrial environmental performance. Its conceptual introduction has been credited to Frosch and Gallopoulos[15] in 1989. Substantial work in this field has been conducted since the early 1990s by the Center for Sustainable Systems and other institutes, with the term "industrial ecology" formally introduced in 1995 by Graedel and Allenby[16]. Today, the practice encompasses many activities from the integration of environmental decision making into product development to the evaluation and improvement of industrial processing systems in order to minimize plant-, company-, or industry-wide impacts during production. At a general level, industrial ecology uses analytic approaches to identify major environmental impacts resulting from production and to achieve concrete industrial environmental performance improvements.

Multiple methods of product and process environmental evaluation can be used to assist in this identification and improvement, including Environmental Impact Assessments, Life Cycle Analysis, and Economic Input/Output Analysis[17]. Life Cycle Analysis (LCA) is one of the most widely adopted methods in industry due to its comprehensive coverage of environmental impacts at every stage of a product's life.

LCA requires the evaluation of process or product impacts within a set of boundaries. These boundaries can extend to a full product life cycle – from material extraction through production, use, and disposal – but can be bounded more narrowly in the case of an industrial process evaluation, or more widely in the case of an industry-wide or multi-industry analysis. The generally accepted approach to conducting comprehensive LCAs is discussed in the ISO 14040 – 14043 standards[18] which lay out detailed requirements for bounding product systems, setting the criteria for analysis, evaluating products consistently, and reviewing and reporting results.

---

[15] Frosch, R.A. and Gallopoulos, N.E. *Strategies for Manufacturing.* Scientific American. Number 261(3). 1989. Pages 144-152.

[16] Graedel, T.E. and Allenby, B.R. *Industrial Ecology.* AT&T and Pearson Education, Inc. 1995, 2003.

[17] Keoleian, Gregory A. and Spitzley, David V. *Sustainability Science and Engineering, Chapter 7: Life Cycle Based Sustainability Metrics.* Elsevier A.B. 2006. Pages 127-159.

[18] *Environmental Management – Life Cycle Assessment – Principles and Framework.* International Standards Organization (ISO). 1997. Reference # ISO 14040:1997(E). Page iv.

When evaluating and improving environmental performance in industry, distinctions between product and process lead to different needs. Product development is treated as a separate function from production process design and operations at most companies, with limited overlap during the product development process to ensure feasibility of production. Decisions relating to environmental impacts are therefore distinct[19]. Product developers are responsible for material and process selection to achieve the functionality of a given product, and therefore have the capacity to control environmental impacts from material inputs and, on a general level, processing. However, these materials and processes are treated as inputs; improvements to the specific environmental impacts of a material are ultimately the responsibility of upstream suppliers and improvements to processes are the responsibility of process designers and production planners. This distinction is critical in the development of WELE and the range of decision making potential incorporated into the tool.

2.4 Environmental Product Design Methods and Tools

In addition to LCA methods used for comprehensive environmental impact analysis and public reporting, many companies use internal tools to identify environmental improvement opportunities during the product development process. As discussed in the introduction to this research, making such decisions is frequently difficult and uncertain before all product materials and processes are identified. Therefore, tools used during this stage typically focus on design decision making and/or selected metrics (e.g. CO_2 equivalent) that can act as indicators for total product impacts without requiring full product evaluations through comprehensive LCAs.

The Center for Sustainable Systems has created frameworks for environmental product development and conducted studies on approaches and tools that can be used to integrate LCA into development. Several studies cover the process of defining product systems, identifying goals and metrics to estimate critical environmental impacts, and methods for achieving environmental improvement[20]. Others cover ways in which LCA elements can be used during product development as well as the challenges of integrating LCA into the development process[21]. The Center is also credited with developing the Life Cycle Design Framework in partnership with the National Pollution Prevention Center and U.S. Environmental Protection Agency. This framework provides detailed guidance on the integration of LCA into product development and the goals, principles, and management needed to support the use of LCA over time[22].

---

[19] Discussed in detail in Graedel, T.E. and Allenby, B.R. *Design for Environment.* AT&T and Pearson Education, Inc. 1998. Pages 12-13.

[20] Keoleian, Gregory A. and Menery, Dan. *Sustainable Development by Design: Review of Life Cycle Design and Related Approaches.* Air & Waste. Volume 44. May 1994. Pages 644-668.

[21] Keoleian, Gregory A. *The Application of Life Cycle Assessment to Design.* Journal of Cleaner Production. Volume 1. Number 3-4. 1993. Pages 143-149.

[22] Keoleian, Gregory A. et al. *Life Cycle Design Framework and Demonstration Projects.* National Pollution Prevention Center. July 1995.

A particularly comprehensive review of environmental decision making tools used in product development is "Product Design for Environment: A Life Cycle Approach"[23], which lays out the wide variety of methods and tools available to developers. In addition to LCA methods, parallels between environmental and product functionality decision making are laid out as well as methods like Design for Environment and specific strategies to improve environmental performance at individual life cycle stages through product development decisions.

Design for Environment is a widely used approach to environmental decision making, though it is practiced in many different ways by individual companies. Ideally, it is intended to be used as one of many considerations during product development including functionality during use, reliability, manufacturability, testability, and others. These as a whole are categorized as Design for X[24], and developers must keep each of these goals in mind when making decisions about a product's design and engineering. Through this approach, environmental decisions are integrated with other goals rather than being treated as post-development decisions.

Case studies and public information on individual companies show a range of Design for Environment practices tailored to each company's product development process. An early study of practices at Motorola[25] discusses the use of a matrixed scoring system for use during development that incorporates qualitative and quantitative measures of critical environmental impacts. Similar scoring systems are used at many industrial product companies, particularly those involved in electronics, appliances, and furniture production where development occurs through a long iterative process and involves multiple material and process options. A representative example of these types of scoring systems is the modified Environmentally-Responsible Product Matrix[26]. Other systems connect environmental decision making to existing product development tools like the Pugh Selection Matrix[27], Taguchi methods for product quality[28], and production efficiency targets[29].

---

[23] Giudice, Fabio et al. *Product Design for Environment: A Life Cycle Approach.* CRC Press. 2006.

[24] Graedel, T.E. and Allenby, B.R. *Design for Environment.* AT&T and Pearson Education, Inc. 1998. Pages 15-16.

[25] Hoffman, William. *Recent Advances in Design for Environment at Motorola.* Journal of Industrial Ecology. MIT and Yale University. Volume 1. Number 1. 1997. Pages 131-147.

[26] Graedel, Thomas and Howard-Grenville, Jennifer. *Greening the Industrial Facility.* Springer Science and Business Media, Inc. 2005. Pages 505-520.

[27] Graedel, T.E. and Allenby, B.R. *Industrial Ecology.* AT&T and Pearson Education, Inc. 1995, 2003. Pages 96-97.

[28] Carnahan, James. *Trade-Off Modeling for Product and Manufacturing Process Design for the Environment.* Journal of Industrial Ecology. MIT and Yale University. Volume 2. Number 1. 1997. Pages 79-92.

[29] Sheng, Paul. *A Process Chaining Approach toward Product Design for Environment.* Journal of Industrial Ecology. MIT and Yale University. Volume 1. Number 4. 1998. Pages 35-55.

Most often, targets for environmental performance are used in combination with these systems to set priorities for environmental decision making[30]. Targets can vary widely by industry depending on the environmental impact areas that are most significant. For electronics, the use phase is often particularly critical due to energy consumption in this phase of the life cycle. Regulations in Europe requiring the takeback of products at the end of life[31] and prohibiting the use of certain materials due to toxicity risk[32] have also driven a greater emphasis on design for remanufacturing and recyclability in this industry. Similarly, appliance manufacturers are driven by a combination of energy and water consumption during the use phase and are also influenced by takeback and material requirements in Europe that ultimately influence global product priorities.

By contrast, the furniture industry faces end of life requirements in regions like Europe but is also guided in the U.S. by Leadership in Energy and Environmental Design (LEED) building requirements for indoor environmental quality, which restrict materials that offgas potentially toxic chemicals, and to an extent requirements for material recycled content and building-wide energy consumption. Other environmental considerations such as greenhouse gas emissions often drive product development targets due to corporate climate change reduction goals.

These industry-specific and general goals for environmental performance are then translated into product development targets. For example, Steelcase's efforts to provide a simplified set of carbon dioxide equivalent, material toxicity and recyclability targets to product developers (as discussed in Section 4.0) is based on its broader goals of climate change mitigation, toxicity risk elimination, and product takeback.

While internal scoring systems and policies help product developers independently prioritize environmental decisions, providing data for this process can be challenging even when metrics are simplified. Many companies therefore rely on external environmental expertise provided by product certifiers or consultants.

---

[30] Review of publicly available information on Design for Environment practices at multiple companies. Those with particularly robust information and/or well-known practices include but are not limited to HP (www.hp.com/hpinfo/globalcitizenship/environment/index.html), Herman Miller (www.hermanmiller.com/CDA/SSA/Category/0,1564,a10-c382,00.html), Interface Fabrics (www.interfacesustainability.com/) and Sun Microsystems (www.sun.com/aboutsun/environment/index.jsp). All websites last accessed April 2008.

[31] http://ec.europa.eu/environment/waste/weee/index_en.htm Last accessed April 2008.

[32] www.ul-europe.com/en/solutions/services/rscs.php Last accessed April 2008.

One external group that has proved particularly relevant to the furniture industry is McDonough Braungart Design Chemistry, which maintains the Cradle to Cradle product certification program[33]. Herman Miller, a Steelcase competitor, has documented its own experience with this program[34] (Steelcase also uses the program). It is evident from the case study that while external evaluation significantly streamlines decision making, the challenges of collecting and evaluating data even with external assistance are significant.

Some companies have taken the integration of expertise a step further and included environmental experts on their product development teams. In addition to its external certifications, Herman Miller also has "design for the environment" teams that work with product development teams to evaluate products[35]. HP, a U.S. based electronics firm, takes a more integrated approach by adding an environmental expert to product development teams or delegating environmental decision responsibilities to an individual within each team[36].

Manufacturers responsible for final assembly of products and distribution to customers have a particular incentive to work with their upstream suppliers on initiatives to improve environmental performance in components produced outside the company. An interesting example is Sun Microsystems, which works with its suppliers to eliminate materials that are not compliant with European toxicity requirements[37]. Steelcase and other companies work in similar ways with their suppliers.

A final approach to environmental decision making in product development is the use of data-driven tools for evaluation. A number of existing tools are designed for in-depth analysis. Others integrate a data driven approach into product development or otherwise streamline calculations of impacts. However, the use of such tools by manufacturing companies appears to be somewhat limited in practice.

Life cycle analysis software is designed to allow the creation of product profiles that incorporate all product components as well as the materials and processes feeding into the production of each component. The impacts of material production before assembly are calculated as part of individual material impacts that are then included through their connection to product assemblies. Use and disposal phases are also integrated in these profiles to provide a full picture of life cycle impacts. The two most widely used programs are SimaPro and GABI, and, as discussed in Section 3.0, these were considered as potential platforms for WELE. While these software options provide a valuable

---

[33] www.mbdc.com/c2c_home.htm Last accessed April 2008.

[34] Rossi, Mark et al. *Design for the Next Generation: Incorporating Cradle-to-Cradle Design into Herman Miller Products.* Journal of Industrial Ecology. MIT and Yale University. Volume 10. Number 4. 2006. Pages 193-210.

[35] www.hermanmiller.com/CDA/SSA/Category/0,1564,a10-c609,00.html. Last accessed April 2008.

[36] www.hp.com/hpinfo/globalcitizenship/environment/productdesign/design.html.Last accessed April 2008.

[37] www.sun.com/aboutsun/ehs/ehs-design.html. Last accessed April 2008.

framework for in-depth LCAs, they are limited in their usability by product developers without training in LCA methodologies or use of the software. Therefore, without some modification, their existing applicability to product development is limited.

Other efforts to develop simplified tools for product environmental assessment have been made. One of the most visible is the EIO-LCA model[38], which uses input-output analysis as the basis for selecting and evaluating product impacts. While this approach has benefits in accounting for certain impacts, it has limitations in its calculation method and its usability by non-experts. In particular, the tool's aggregation of data to industry-wide and commodity classifications makes it difficult to conduct evaluations at a high level of specificity. In addition, its reliance on user knowledge of product inputs can risk omission of critical impacts. Other tools designed specifically for the product development process have also been created, though their current application in industry is limited. Those discussed in-depth include EcoDS, an internet-based LCA tool[39], a collaborative tool based on existing product development software created by Borland and Wallace[40], a learning-systems based surrogate LCA model[41], a multiagent system (MAS)[42], and ELDA for end of life calculations[43].

The case studies of these tools provide insights into their structures as well as the challenges facing their development. While their benefits are clear due to the provision of solid data for environmental decision making within a presumably usable interface, developing a usable interface and integrating the tools into product development are challenging. Some critics, particularly regarding very early stage product concept design, point out the limitations of an analytical tool's usability within an iterative and creative process[44]. However, the value of such a tool is still acknowledged so long as it can be used within existing product development approaches and methods.

---

[38] www.eiolca.net/about.html. Last accessed April 2008.

[39] Biswas, Gautam et al. *An Environmentally Conscious Decision Support System for Life Cycle Management.* Journal of Industrial Ecology. MIT and Yale University. Volume 2. Number 1. 1998. Pages 127-142.

[40] Borland, Nick and Wallace, David. *Environmentally Conscious Product Design: A Collaborative Internet-Based Approach.* Journal of Industrial Ecology. MIT and Yale University. Volume 3. Numbers 2&3. 2000. Pages 33-46.

[41] Sousa, Inês et al. *Approximate Life Cycle Assessment of Product Concepts using Learning Systems.* Journal of Industrial Ecology. MIT and Yale University. Volume 4, Number 4. 2001. Pages 61-81.

[42] Kraines, Steven et al. *Internet-Based Integrated Environmental Assessment, Part II: Semantic Searching Based on Ontologies and Agent Systems for Knowledge Discovery.* Journal of Industrial Ecology. MIT and Yale University. Volume 10, Number 4. 2006. Pages 37-60.

[43] Rose, Catherine. *Design for Environment: A Method for Formulating Product End of Life Strategies.* Department of Mechanical Engineering, Stanford University. November 2000.

[44] Ryan, Chris. *Information Technology and DfE: From Support Tool to Design Principle.*

2.5 Steelcase Environmental Initiatives

Steelcase has a longstanding commitment to corporate environmental efforts through its company-wide policies, operations, and product designs. These include plant-level improvements, including those leading to the first LEED certified industrial facility in the U.S., manufacturing process improvements, renewable energy purchasing, and many other initiatives. Steelcase has also invested resources in developing its products to meet external environmental standards as well as internal performance targets. A particularly relevant effort to improve product performance was the test development of a material analysis tool for concept designers created by the company's European environmental team. This tool informed the development of WELE and is discussed in Section 2.6.3.

2.6.1 Certifications and External Reporting

Steelcase certifies its products through a number of external programs and provides reports on products' environmental performance when relevant to a particular market. The primary programs used for certification are Cradle to Cradle (C2C), GREENGUARD, and SCS Indoor Advantage, with LEED and Environmental Product Declarations also playing critical roles in external reporting.

The C2C certification program measures product environmental performance across multiple categories including material toxicity, energy consumption, water consumption, reutilization through recycling and other methods, and social responsibility. It is discussed in further detail in Section 4.4.

The GREENGUARD[45] and SCS Indoor Advantage[46] programs test and certify products for compliance with indoor air quality emission targets. This is a key element of the Leadership in Energy and Environmental Design (LEED) certification process for buildings and is therefore critical in meeting Steelcase's customer needs[47]. Steelcase also works with architects to measure its products' contributions to LEED achievement as a whole. The areas of LEED to which a product can contribute, in addition to Indoor Environmental Quality, are in the Materials & Resources and Innovation categories.

Beyond external certifications, Steelcase also releases Environmental Product Declarations (EPDs) on selected products' environmental performance. As discussed in Section 1.5, EPDs follow a rigorous evaluation and reporting process and are conducted by environmental experts. These declarations are separate from the intent of WELE due

---

[45] www.greenguard.org Last accessed April 2008.

[46] www.scscertified.com/iaq/indooradvantage.html Last accessed April 2008.

[47] http://leedonline.usgbc.org/ Last accessed April 2008.

to the need to meet external standards. However, data from product evaluations in WELE can be used by the experts constructing these external reports.

2.6.2 Internal Design Targets

Internally, Steelcase has set targets for product performance that specifically help product developers make environmentally preferable decisions. These focus on environmental performance areas that can be measured with relative ease in lieu of a more comprehensive method of analysis.

The main criteria currently used by product developers (all discussed in Section 4.0) are global warming potential as represented by carbon dioxide equivalent emissions, recycled content and recyclability of materials, and the requirements for minimal material toxicity that are part of the C2C certification system.

The stage gate review process allows environmental managers to assist product developers in meeting these basic targets. In addition, some products that are specifically intended to achieve high environmental performance have additional requirements and targets that are reviewed during the stage gate process.

These simplified metrics and periodic reviews have the advantage of providing guidance on environmental performance with minimal investment. However, moving beyond these metrics by integrating LCA methods into earlier stages will ensure better environmental decision making overall. For this reason, WELE is designed to integrate existing metrics but also allow more comprehensive analysis of environmental performance in multiple impact categories and throughout the whole product life cycle.

2.6.3 Relevant Steelcase Tool Development Work

One previous Steelcase environmental product development effort was particularly relevant to the creation of WELE. A team of environmental experts in Steelcase's European division developed a general Excel-based analysis tool for conceptual designers to use in the identification of environmentally preferable material options. The initial screen of this tool is shown in Figure 1.

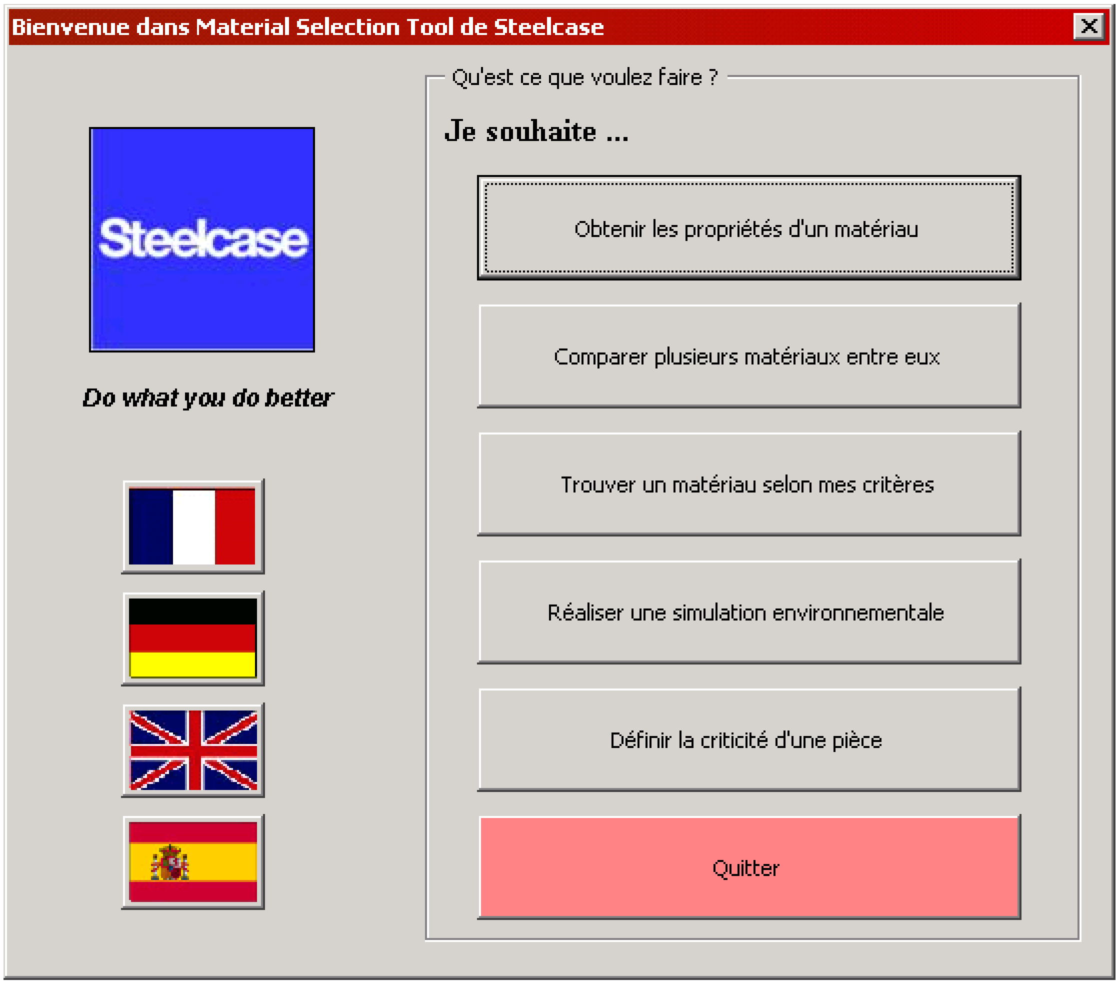


Figure 1 Main Entry Screen of Steelcase European Material Analysis Tool

This tool was not put into use, but operated similarly to the general material analysis section of WELE. Lessons learned from the aspects of the European tool were taken into consideration during WELE's development.

3.0 Tool Structure Development

The beta version of the Steelcase environmental analysis tool, with the working title of Wizard for Environmental Life Cycle Evaluation (WELE), was developed through a number of stages. SimaPro, a widely used life cycle analysis (LCA) program, was selected as the platform and the tool was developed through the "wizards" component of this program. WELE was then tested at various points with representatives from Steelcase in Grand Rapids and Strasbourg as well as representatives from IDEO[48]. PRé Consultants and their representatives at EarthShift[49] provided additional input on coding feasibility at various points.

In general, feedback on the approach and structure of WELE was positive. However, several challenges were encountered due in part to the disparate needs of user groups and in part to limitations on coding in SimaPro. Regarding the first finding, the tool was ultimately developed with the needs of Steelcase Grand Rapids in mind[50], and lessons learned about the differences in needs between divisions and companies are included as supplementary conclusions. Regarding the second, suggestions on ways to improve SimaPro's flexibility and usability have been submitted to PRé Consultants, and a recommendation is made for Steelcase to explore alternative interfaces in the short term.

3.1 Platform Selection

The first step of developing the WELE interface was to select a platform to support user interface development and input data. Several paths were considered: using an existing LCA platform like SimaPro or GABI, using an Excel or Access based platform in which format flexibility and data linkages to existing LCA data sets could theoretically coexist, and coding a tool from scratch that would be tailored to Steelcase's needs. A fourth option was discovered during development, in which LCA data from an existing platform could be inputted into engineering software such as ProE or another CAD platform. This final option could also be used in tandem with one of the other options. The first option of building WELE into an existing LCA platform was selected for a variety of reasons, as discussed below. However, several other paths still appear to merit exploration due to their superior flexibility in designing a usable interface.

---

[48] During this project, Steelcase and IDEO identified opportunities for some crossover use of the tool. However, as discovered during development needs within the two groups were significantly different and the long-term potential to share use of the tool separately came into question. This led to the conclusion that the tool should remain within Steelcase in the immediate future.

[49] Pre Consultants are the developers of SimaPro software. Earth Shift is their primary contractor in the U.S. to provide support on SimaPro use and development of tools, such as "wizards", within the software.

[50] Steelcase's Grand Rapids group is where North American product development is based and is where this project originated. While input from other groups was informative and appreciated, the tool first needed to meet the needs of product development in this central location.

The criteria for selecting a platform was based on feasibility of interaction design, reporting content and formats, and the availability of multiple data sources as inputs to the tool. Each potential platform presented some advantages and disadvantages in these areas of concern, as discussed in Table 2.

Table 2 Advantages and Disadvantages of Tool Platform Options

	Interaction Design	Reporting	Data Availability
Existing LCA Tool, e.g. SimaPro[51] or GABI[52] (least time intensive)	Primarily focused on LCA experts; non-expert options limited to "wizards", a simplified coding process for step-by-step instructions and model building	Existing LCA reporting methods and output format included (notably, visual "network/tree" view of product impacts; new report criteria can be added	Significant amount of industry data on environmental impacts included; custom data can be entered in forms or linked from external databases
Excel / Access	Increased flexibility in building input screens that do not have to be accessed linearly; concerns about complexity of full product analysis	Greater flexibility in visual and data output formats; limited potential to include network/tree approach	All data inputted from external sources or created from scratch; input from existing LCA software limited by terms of use
Custom Coding (most time intensive)	Full potential for easy and relevant interaction, but time limitation to develop and maintain is prohibitive	Full flexibility in visual and data output formats, but again constrained by time limitations	All data inputted from external sources or created from scratch; input from existing LCA software limited by terms of use
LCA Tool Linked with CAD Program, e.g. Pro-E	Use of CAD as the interface benefits from developer familiarity; some concerns about non-users of ProE being cut out of analysis	Instantaneous reports within CAD; creating permanent reports to share outside the program in useful data formats is uncertain	Data stored in SimaPro or other LCA software and linked indirectly; questions remain about procedure of data linking

An Excel or Access based format appears to offer high potential for development of a usable interface while minimizing coding requirements (the ultimate limitation that excludes coding from scratch as an option). For example, the material analysis tool

---

[51] Details on SimaPro available at www.pre.nl/simapro/. Last accessed April 2008.
[52] Details on GABI available at www.gabi-software.com/. Last accessed April 2008.

developed by Steelcase in Strasbourg used Excel as its platform[53]. However, this tool was limited to basic material comparisons and reporting, and, when the additional complexity of evaluating a full product and its components are added, concerns about the interface and particularly the reporting capabilities of this platform emerge. Even more significant are the concerns about data inputs and how this data would be vetted and updated over time to maintain accuracy. Theoretically, the Excel database could be linked to existing LCA software to access updated information, but this is limited by the software providers' terms of use. Therefore, while there are some advantages in making the process more intuitive, specific interface and reporting limitations as well as the substantial need for data management present concerns with this approach.

The CAD-linked approach also presents exciting opportunities. Integrating environmental analysis into product design software is by far the simplest and most intuitive way to show impacts as the product is being developed. In addition, a link to existing LCA software is not limited by terms of use and would allow access to a breadth of data inputs. However, concerns about reporting this information outside the CAD software are significant and the integration with CAD limits direct interaction to only the team engineer, excluding other team members that could also contribute to decision making. In addition, this approach has not been tested[54] and questions have been raised about impacts on stability of CAD programs as well as about the details of LCA and CAD software linkages. Therefore, while this approach has long term potential, it was not pursued in great depth as part of this research.

Using an existing LCA platform like SimaPro presents very different advantages from those of an Excel/Access platform. SimaPro and GABI, the most widely used LCA tools, already provide a well structured platform for building product profiles, incorporating materials and processes into these profiles, and translating complex aspects of this data into measures of environmental performance. Much of the work that would be conducted in Excel or another platform would involve replicating this process. In addition, SimaPro provides a significant reserve of standard environmental profiles for various materials and processes and allows the addition of new profiles through the software itself or through connections to external databases that feed into the software. The downside of using such a platform, as discovered throughout this project, is the limitations on user interface design inherent in the "wizards" coding process. However, creating a functional tool through this process was feasible and future improvements to "wizards" coding can mitigate some user interface concerns.

---

[53] See Section 3.2.

[54] Conversation with Pre Consultants and Earth Shift representatives on known uses of SimaPro in connection with CAD programs.

In selecting an existing LCA software application, Steelcase determined that SimaPro provided an additional advantage over other options in that it was already being used by Steelcase's environmental experts for final product LCAs and provided similar functionality in terms of data storage, construction of product profiles, and evaluation and reporting tools. Based on this existing connection and the advantages of using an existing LCA platform, SimaPro was used as the basis for the beta version of WELE.

It remains important to recognize the advantages of other approaches, and based on the limitations encountered during the project there may be some value in exploring alternative interfaces further. If an alternative is pursued, linking to SimaPro would still be a critical element in order to gain the benefits of data storage and analysis.

3.2 Integration with Product Development

The second initial aspect of WELE's development was to identify where and when environmental analysis was critical during product development and how the tool could be designed to integrate with this existing process.

As discussed in Section 2.1, product development at Steelcase follows a fairly standard stage gate process. At a high level, a piece of furniture begins as a general concept, design is conducted to develop a functional product, engineering is conducted to resolve assembly details, and processes and supply chain decisions are made to put the finished piece into production. After each step, a stage gate review is conducted where a variety of groups including environmental managers review and sign off on the product before additional development[55]. An additional stage is often included to review the completed product and glean lessons for future product development efforts. While details on Steelcase's activities in each stage and the stage gate reviews are proprietary, the general process can be understood as described in Section 1.1, Table 1.

Steelcase currently performs general environmental reviews following stages 1 and 2 using selected metrics across all products and more intensive metrics for products specifically marketed based on environmental performance. This analysis is becoming increasingly extensive, and during this research Steelcase determined that its new goal was to include LCAs in the stage gate reviews. This is therefore a primary driver of the WELE tool's functionality during product development.

Based on what is typically known about a product, different levels of environmental analysis are needed at each stage, as discussed in Table 3. This need for multiple degrees of analysis sets the stage for WELE's structure and capabilities.

---

[55] Review of Steelcase stage gate review checklists (proprietary).

Table 3 Environmental Analysis Needs at Each Stage of Development

Stage	Environmental Analysis Needs[56]
0: Concept	Individual material comparisons.
1: Design	Comparisons of product options on a material and full product basis.
2: Engineering	Comparisons of specific materials used by Steelcase (versus generic data) within the selected product option.
3: Process	Comparisons of specific processes and final production design material options within the designed product.
4: Reporting	Full life cycle analysis in compliance with ISO 14040 standards.

An important distinction made early in the research was that WELE would be developed to address needs in stages 0 through 3 but would not be used to complete final and public reports on product environmental performance. This task remains within the Environmental Strategy and Programs department at Steelcase because it requires fundamental expertise in life cycle analysis that is not expected of product developers.

To address the needs in development stages 0 to 3, the tool must accommodate a spectrum of increasingly specific knowledge about the product and the different needs for environmental information based on this changing knowledge. Encouraging fluidity of environmental modeling and results as products are developed over time is also essential in meeting these needs.

To achieve this flexibility and fluidity, WELE's underlying structure is designed to allow developers to build a basic product profile with minimal information and add to the profile as more information about components, materials, and processes become known. WELE also allows multiple versions of the same product to be constructed and compared, which is particularly critical in Phase 1 when multiple product options are being considered. To address the more basic material analysis needs in stage 0, a separate functional area of WELE also allows developers to compare materials without creating a profile of a product with components and multiple materials and processes.

The question of whether it is necessary to build product profiles (i.e. a model of a complete product) was raised at several points throughout this research. At first glance, it can appear that single material comparisons would be sufficient for environmental decision making, as was assumed in the earlier tool developed by Steelcase's European team. While this approach may be sufficient for stage 0, there are particular reasons to evaluate full product assemblies over the course of later development stages.

Essentially, a product is more than the sum of its materials: it is the interaction of these materials in achieving a functional goal, and variations in this interaction can yield a

---

[56] Verified with environmental experts and product developers at Steelcase, Grand Rapids.

variety of results. Because products must meet functional requirements as well as environmental ones, selection of a material due to superior environmental performance can, in some cases, require the use of complementing materials that are less environmentally preferable in order to meet functional goals. As a result, some product designs based on the environmental performance of a single material can be less environmentally preferable than another design that uses a less environmentally preferable material for the same function but is able to minimize product *system* environmental impacts in other aspects of the product.

In addition, developers are being asked not only to consider the most environmentally preferable alternatives but also the total environmental impacts of the products they produce. While a single material selected early on can contribute significantly to the total impacts, no single material is a good indicator of the sum of impacts. By contrast, an evaluation of whole product design even in the earliest stages of development appears to provide a more solid approximation of what the total impacts will be. This phenomenon was seen in the case studies summarized in Section 6.0.

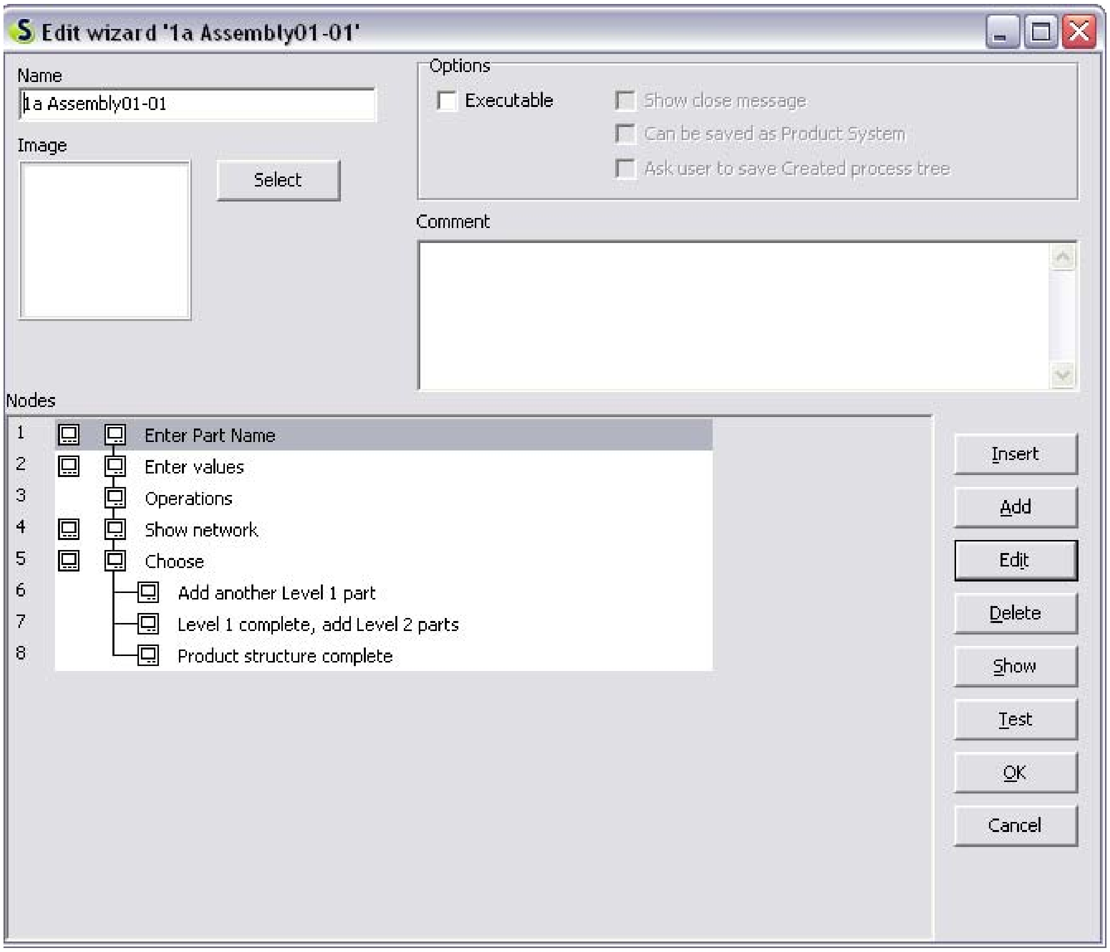
3.3 Tool Structure and Interface

WELE was built in SimaPro based on the needs at different stages of development using the "wizards" process provided within the software. This process, most commonly seen in the installation process for computer software, takes the user through a linear process of selecting actions and inputs to produce a model and report on the results of that model. The wizards are based on a series of commands that are summarized briefly in Appendix A. More detailed information is included in the SimaPro Wizards Manual available from PRé Consultants[57].

Wizards are coded in one section of SimaPro and linked to each other, resulting in an interface where the user can make selections and build models and reports. A sample coding screen is shown in Figure 2 and a sample of the interface visible to users is shown in Figure 3.

---

[57] *SimaPro 7: Wizards Manual.* PRé Consultants. 2007. www.pre.nl/download/manuals/WizardManual.pdf Last accessed April, 2008.



Edit wizard '1a Assembly01-01'

Name: 1a Assembly01-01

Image

Options

☐ Executable

☐ Show close message

☐ Can be saved as Product System

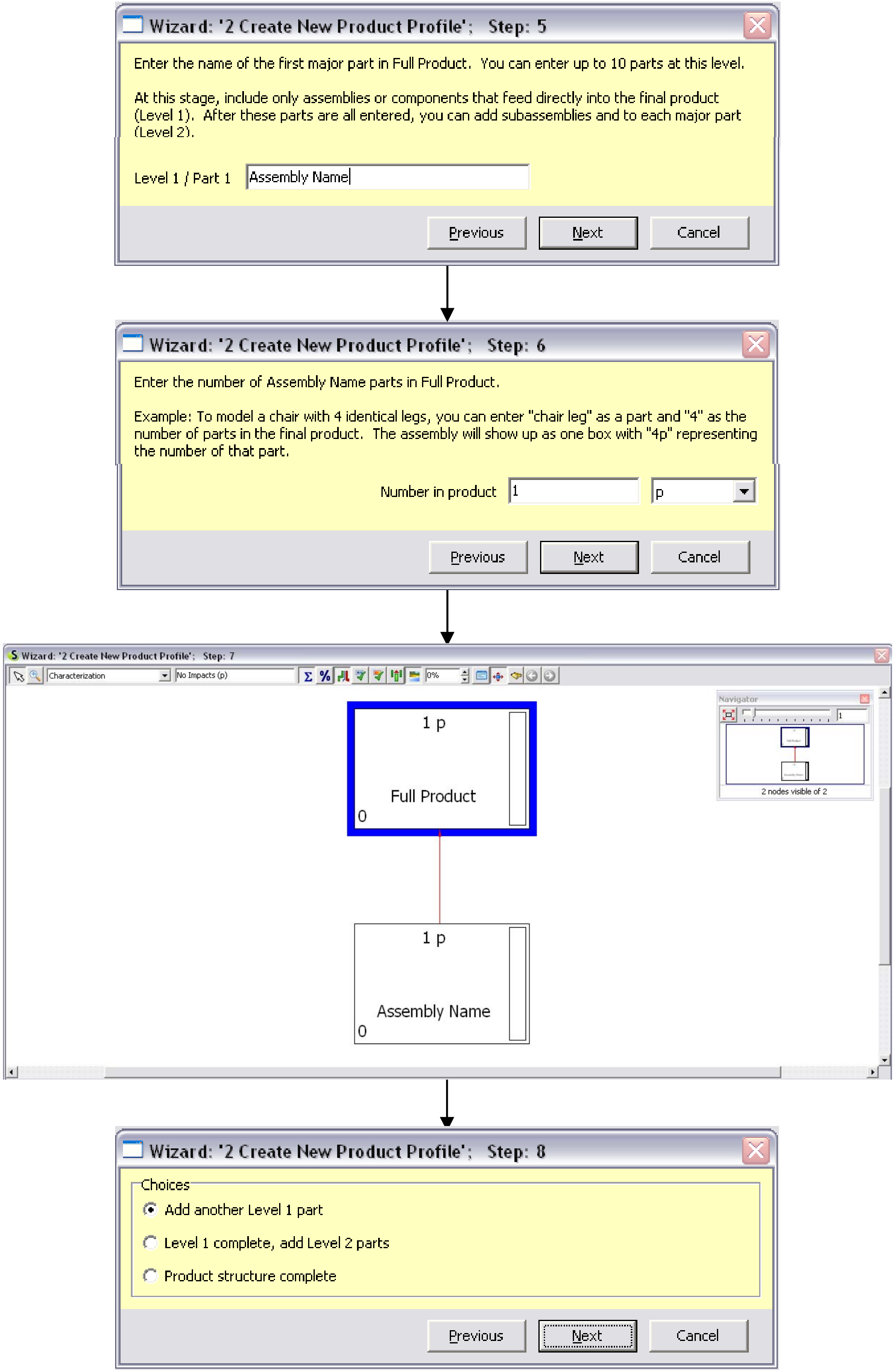
☐ Ask user to save Created process tree

Comment

Nodes

1 Enter Part Name
2 Enter values
3 Operations
4 Show network
5 Choose
6 Add another Level 1 part
7 Level 1 complete, add Level 2 parts
8 Product structure complete

Figure 2 Sample Wizard Coding Screen



Wizard: '2 Create New Product Profile'; Step: 5

Enter the name of the first major part in Full Product. You can enter up to 10 parts at this level.

At this stage, include only assemblies or components that feed directly into the final product (Level 1). After these parts are all entered, you can add subassemblies and to each major part (Level 2).

Level 1 / Part 1 Assembly Name

Wizard: '2 Create New Product Profile'; Step: 6

Enter the number of Assembly Name parts in Full Product.

Example: To model a chair with 4 identical legs, you can enter "chair leg" as a part and "4" as the number of parts in the final product. The assembly will show up as one box with "4p" representing the number of that part.

Number in product 1 p

Wizard: '2 Create New Product Profile'; Step: 7

Wizard: '2 Create New Product Profile'; Step: 8

Choices

● Add another Level 1 part

○ Level 1 complete, add Level 2 parts

○ Product structure complete

Figure 3 Interface Results of Sample Wizard Coding

SimaPro relies on a structural division of products into components with the addition of respective materials and processes to reflect the multiple inputs that contribute to a product's total impacts. The general structure is shown in Figure 4. Components of a product are treated as empty boxes to which materials, processes, and transportation profiles can be added. Each product is linked to a "life cycle" into which use and disposal profiles can also be added. Information on environmental impacts is included in the profiles of each material, process, transportation mode, use profile, and disposal profile. By linking these to a product assembly, a report can then be generated for the full product using a selected method of life cycle impact analysis.

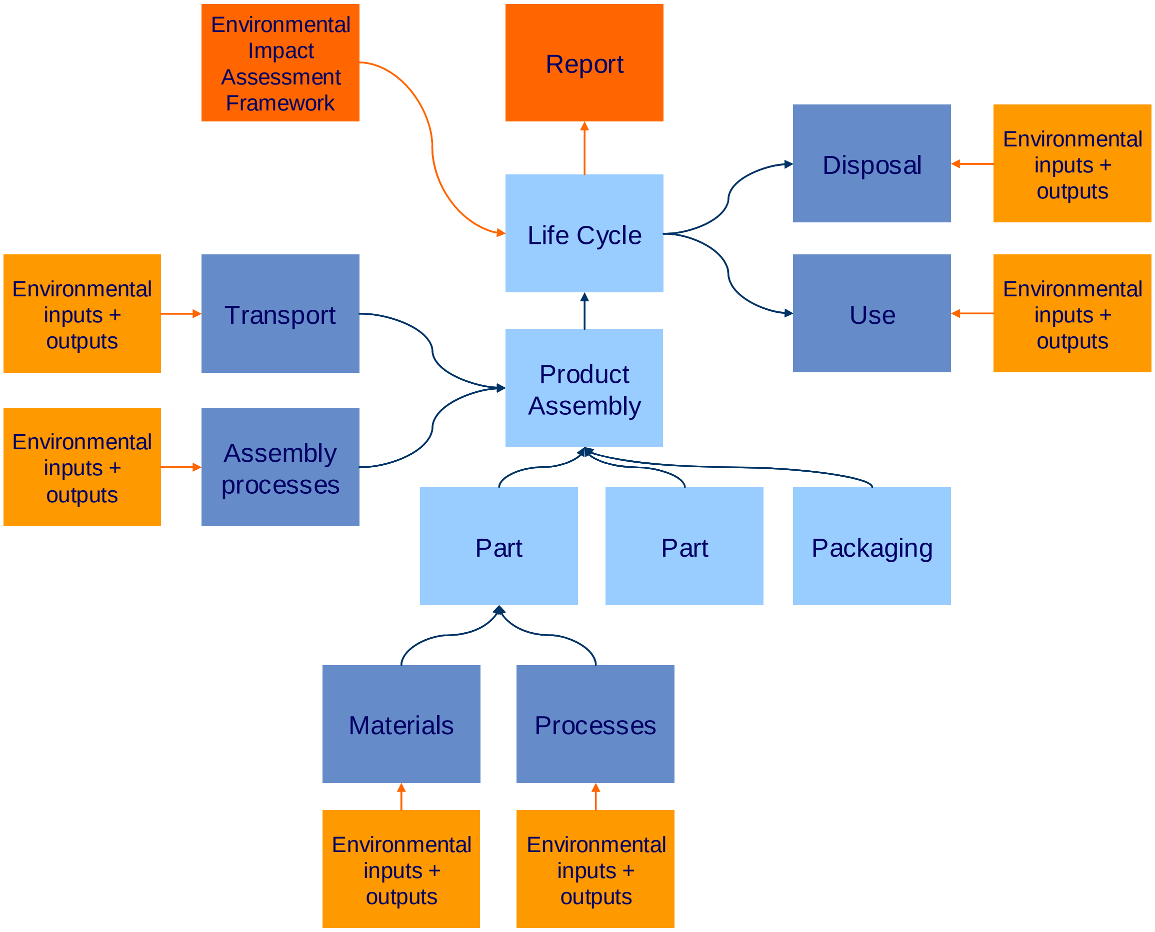


Figure 4 SimaPro Division of Product and Environmental Elements

The coding of the tool was based on the step by step wizard process and the division of product elements, data, and reporting described above. It therefore incorporates steps that are necessary for product evaluation as well as steps that are necessary for the tool to be usable within the programming limitations.

When a user enters SimaPro, they are presented with a main screen, shown in Figure 5, and can select any of the options to proceed through a set of decision making screens to produce profiles and reports.

Figure 5 WELE Categories

Beyond the introduction and tutorial designed for first time users, the remaining pathways and their functions allow different types of analysis, as outlined in Table 4.

Table 4 Primary Decision Paths in WELE

Pathway	Function
1 Evaluate Materials	The user can select individual materials (or processes or transportation profiles) and compare them to other materials for a basic analysis of environmental impacts. This section is most useful for Stage 0 of development.
2 Create New Product Profile	The user creates components of a product and links them together to create an assembly. The assemblies can then be added to as the product is developed.
3 Profile Storage	This manual step is essential due to programming limitations within SimaPro. It provides instructions on storing newly created product assemblies in a certain location so they can be accessed again at later stages.
4 Refine Product Profile	This step allows users to add materials, processes, transportation profiles, and other elements to the assembly. These inputs are automatically linked to environmental impacts and collectively contribute to an assessment of the product's profile and total impacts.
Evaluate Products	The user can create reports using a variety of metrics to evaluate a single product or compare product impacts, which is particularly critical during the design phase when multiple product iterations are in development.

Copying profiles and creating variations are supported through the profile creation steps. Each of the product profile and reporting steps can also be revisited as the product is developed over time to add new components to the assembly as well as new materials, processes, transportation profiles and other elements. This is not only valuable during new product development but critical for redesigns where a completed product may be revisited to make further modifications after a period of time.

With the exception of the profile storage path, each is a step by step and/or decision tree process in which the user inputs known information about the product in question and uses the wizards process to generate results. The critical elements of the decision trees used to code these paths are provided in Appendix B.

3.4 Tool Development and Testing

The beta version of WELE was tested at various points in its development with Steelcase product developers in Grand Rapids, the Steelcase environmental team in Strasbourg, France, and representatives from IDEO. Discussions were also held with PRé Consultants and EarthShift representatives to determine how several usability concerns could be addressed in the short term and the future.

The Steelcase and IDEO teams provided feedback on the tool's usability and this feedback was incorporated to the greatest extent possible within the software's constraints. The teams also provided feedback on the fundamental functionality and usability of such a tool.

3.4.1 Usability

The basic structure and purpose of the tool was understood by users and there were no significant issues with the division of product elements between the product structure, material and process data, and reporting. However, several users raised concerns about the time it took to proceed through some of the steps and the repetitive nature of some areas like material selections for comparison. This issue remains critical, as developers will use the tool on an infrequent basis and need to be able to access it without relearning the mechanisms of the tool.

While some of these issues could be addressed and were resolved in subsequent versions of the tool, a significant number were traced back to limitations presented by the SimaPro coding requirements. As a result, many interaction elements that were desired could not be included to make the process more intuitive and less time consuming than in the first beta version.

A list of the main concerns about coding limitations was compiled and shared with representatives from PRé Consultants (Appendix C). The representatives noted that they were aware of some of these limitations and were particularly interested in improving SimaPro for non-expert users in the long run[58]. While many of the changes would take time to develop, there appeared to be some value for Pré as well as Steelcase in improving the interaction development within SimaPro.

While these improvements will be beneficial, there remains the question of usability in the short term. Based on the early analysis of different platforms, it seems that there may be value in revisiting some of the alternatives to building a tool within SimaPro. In particular, the CAD-linked approach in combination with SimaPro or the Excel/Access approaches hold some promise if an interface with SimaPro databases can be achieved.

---

[58] From individual discussions with Lise Laurin from EarthShift and Michiel Oele from PRé Consultants.

3.4.2 Differences in Needs

While most concerns could be traced to basic usability issues, an interesting finding throughout this research was the difference in evaluation needs across organizations and departments within Steelcase. Steelcase's groups in Grand Rapids and Europe are organized in significantly different ways[59], and IDEO's approach and product focus lead to even greater distinctions in their need for support in evaluating the environmental impacts of products during development[60].

Steelcase's Grand Rapids headquarters has a small team of environmental experts and multiple product development teams working on a wide variety of furniture products at any given time. The environmental staff is not only responsible for working with these teams but also for interacting with a range of other company functions. By contrast, the Strasbourg offices have a similarly sized environmental team that works with a much smaller group of product developers. Therefore, interaction between environmental experts and product developers is more direct in Strasbourg than in Grand Rapids and the quantity of expert involvement in environmental analysis is greater. On the other end of the spectrum, IDEO has an even larger product development team working on a wider variety of products, and its ratio of environmental experts to product developers is lower than that at Steelcase.

The proportion of environmental experts to product developers in Grand Rapids shows that environmental staff is unable to dedicate time to every product development team, particularly if environmental analysis of specific materials and design decisions is to be integrated into each stage of development. This limit on resources drives the need to disseminate a level of environmental impact analysis to developers without requiring them to develop the same level of expertise as environmental staff.

The Steelcase division in Strasbourg has different needs due in part to its more substantial ratio of environmental experts to product developers. Essentially, the environmental team can, and to a degree is expected to, manage environmental analysis more directly during development. Anecdotally, it appears from several discussions[61] that this emphasis on expertise is reinforced by an expectation from developers in the European offices that environmental analysis should be conducted by experts rather than developers themselves. This is evidenced in part by European product developers' concerns about using the simpler tool developed by the Strasbourg environmental team prior to this research[62].

---

[59] From discussions with Steelcase environmental experts.
[60] From discussions with IDEO contributors to WELE testing.
[61] From conversations with Strasbourg representatives and CSS discussions.
[62] From discussion with Denise VanValkenburg at Steelcase, Grand Rapids.

By contrast, IDEO has even less capacity to include an environmental expert on each product development team due to its large number of projects. However, a critical difference is that IDEO focuses on rapid turnover of projects, primarily at the early stages of product development, and works with multiple clients, each of which has its own internal review process. Therefore, time limitations are significant and participation in later stage gate reviews and final environmental evaluations are less likely than at Steelcase. In one sense, a tool to evaluate products during development is a valuable proposition due to the high number of projects and minimal environmental expertise. However, the rapid turnover and focus on earlier stages of development necessitate a far less time intensive process of evaluation.

IDEO's structure also necessitated a different functionality for the tool. For the IDEO representatives reviewing WELE, it was of particular interest that the tool would act as an educational device rather than simply an input/output device[63]. This was in stark contrast to the interests at Steelcase, where the goal was to have a results oriented tool requiring only a general understanding of LCA concepts. The educational need at IDEO seems to stem not only from their high product developer to environmental expert ratio but also their rapid work with multiple clients, in which IDEO's developers may be expected to come to the table with an inherent understanding of LCA and the potential impacts of design decisions on multiple stages of the product life cycle.

These differences in the structure and expectations of each team seem to be at the core of the vastly different feedback received from the groups. Usability concerns were most strongly expressed by the Strasbourg team, which also raised questions about the overall purpose of the tool. By contrast, the U.S. team had some usability concerns but focused on technical details of the tool rather than the overall approach. The IDEO team felt comfortable with the underlying structure but needed greater flexibility in terms of user interaction than that which was initially built into the tool.

As these different needs came to light over the course of research, it was clear that the tool was largely meeting the needs of Steelcase in Grand Rapids but that different formats and degrees of complexity may be needed in Europe and at IDEO. Because the Grand Rapids team was the primary client and integrating variations into the tool would add to complexity and confusion over functionality, later iterations were developed based primarily on the needs of the Grand Rapids team.

However, the differences in needs illustrate an interesting point for future development of tools for early stage environmental analysis. The needs and intents of the organization using the tool certainly must be taken into account when determining the structure and elements to be included.

---

[63] From first tool review conducted by IDEO representatives.

In addition, the usability concerns raised by the Strasbourg and IDEO reviewers should not be discounted; nor should those raised by the Grand Rapids team. A number of improvements are needed to bring the tool to an optimal state of use and efficiency. These need to be addressed in the long term by building the platform's capacity to support a user-friendly interface for non-expert users. For tool developers at SimaPro, a platform initially developed for expert LCA analysts, this presents an opportunity to refine existing LCA software and reach a much broader set of users.

3.5 Final WELE Structure and Integration

The final tool structure incorporates feedback from the reviewing teams to the greatest extent possible, but remains somewhat limited due to the platform coding requirements. Therefore, it is expected that the tool will go through several more iterations of development as the SimaPro software evolves to meet non-expert usability needs.

In addition, the alternatives to an integrated tool within the SimaPro software should continue to be explored. There appears to be significant potential for CAD-linked tool or an Excel/Access based interface to fill the usability gap before SimaPro coding is refined.

In terms of integration with Steelcase properties, one round of training has been conducted with development teams at Grand Rapids in addition to the individuals testing earlier iterations of the tool. Additional training sessions are scheduled and a manual has been provided for user reference as the tool comes into full use at Steelcase.

4.0 Reporting

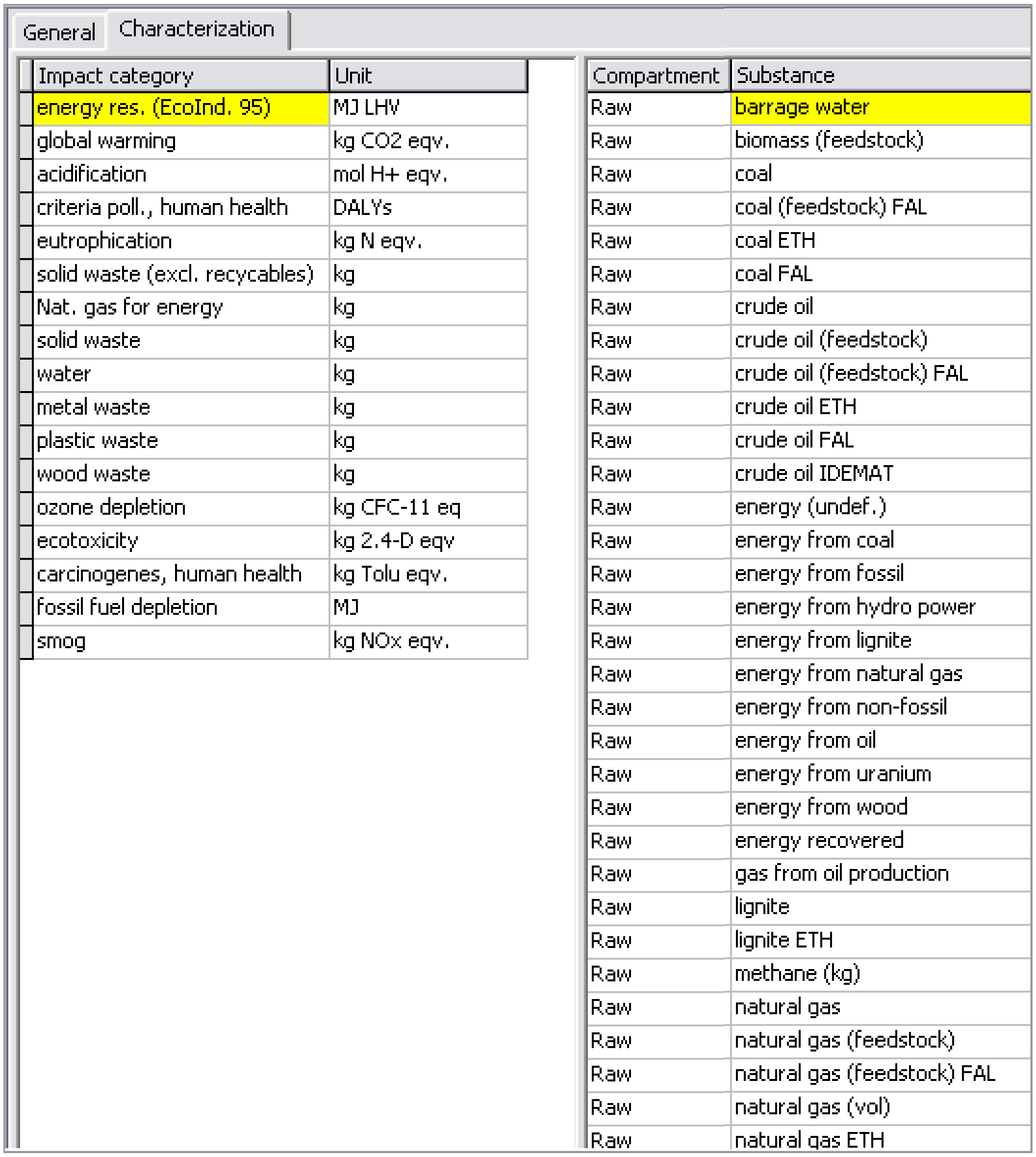
The first part of this research focused on developing the fundamental structure and interface of WELE in which the basic interaction between building a product profile, adding materials, processes and other data, and creating reports was determined. Reporting methods themselves, as well as data inputs, are treated as fundamentally separate areas of SimaPro that connect with the wizards-based WELE interface. Therefore, Steelcase-specific needs in each area were addressed separately from the general tool structure.

There are many different ways to measure environmental impacts, and Steelcase has established internal environmental targets based on certain impact assessment frameworks and individual metrics discussed further in Section 4.2. In addition, Steelcase recently set a goal to incorporate LCA into early stages of product development. This requires the use of life cycle frameworks that address broad environmental impacts throughout the life cycle rather than just the impacts captured by previous metrics. The new and existing approaches were each incorporated into the WELE interface.

4.1 SimaPro Reporting Structure

Reporting in SimaPro relies on environmental impact assessment frameworks that measure and sometimes weight impacts according to the importance of environmental impacts as defined by the framework. The impacts to be measured are stored in an impact assessment profile that can then be applied to a product profile (i.e. a model of a chair or desk product) in order to measure the impacts of its materials, processes, transportation, and other inputs based on the data stored in each input profile.

A sample impact assessment profile is shown in Figure 6. In this profile, the impact categories on the left represent the major areas of environmental impacts and their units of measurement. For example, energy resources is calculated using the assessment framework EcoIndicator 95 and is measured in low heating value megajoules (MJ LHV). Global warming is measured by kilograms of CO2 equivalent (kg CO2 equiv) and ozone depletion is measured by kilograms of chlorofluorocarbon 11 equivalent (kg CFC-11 eq). On the right, each substance that contributes to the major areas of environmental impacts is listed by its name and role in consumption or emissions. For example, the substances in Figure 6 are categorized as “Raw” because they represent consumption of raw materials. Additional substances are categorized as air, water, and other emissions.



Impact category	Unit
energy res. (EcoInd. 95)	MJ LHV
global warming	kg CO2 eqv.
acidification	mol H+ eqv.
criteria poll., human health	DALYs
eutrophication	kg N eqv.
solid waste (excl. recycables)	kg
Nat. gas for energy	kg
solid waste	kg
water	kg
metal waste	kg
plastic waste	kg
wood waste	kg
ozone depletion	kg CFC-11 eq
ecotoxicity	kg 2.4-D eqv
carcinogenes, human health	kg Tolu eqv.
fossil fuel depletion	MJ
smog	kg NOx eqv.

Compartment	Substance
Raw	barrage water
Raw	biomass (feedstock)
Raw	coal
Raw	coal (feedstock) FAL
Raw	coal ETH
Raw	coal FAL
Raw	crude oil
Raw	crude oil (feedstock)
Raw	crude oil (feedstock) FAL
Raw	crude oil ETH
Raw	crude oil FAL
Raw	crude oil IDEMAT
Raw	energy (undef.)
Raw	energy from coal
Raw	energy from fossil
Raw	energy from hydro power
Raw	energy from lignite
Raw	energy from natural gas
Raw	energy from non-fossil
Raw	energy from oil
Raw	energy from uranium
Raw	energy from wood
Raw	energy recovered
Raw	gas from oil production
Raw	lignite
Raw	lignite ETH
Raw	methane (kg)
Raw	natural gas
Raw	natural gas (feedstock)
Raw	natural gas (feedstock) FAL
Raw	natural gas (vol)
Raw	natural gas ETH

Figure 6 Partial View of TRACI Framework Profile

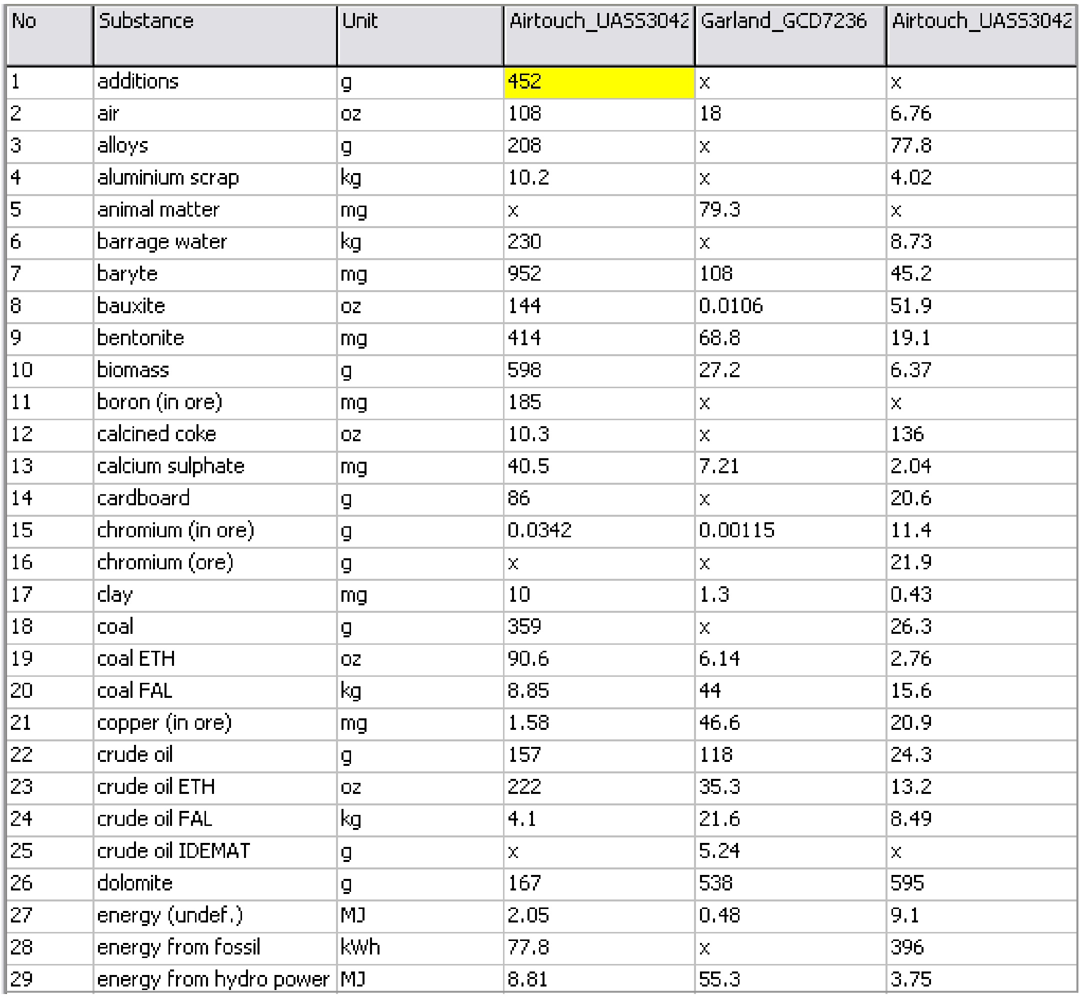
Report outputs are presented in visual and table-based formats. The primary visual representation is typically a bar chart, as shown in Figure 7, though there is some possibility for modification by switching to pie charts, triangular formats, and changing colors and labels. The table based formats, a sample of which is shown in Figure 8, list all impact categories from the assessment framework and the level of impact presented by the product in each category. The table data can also be reorganized by process contribution (each material and process's contribution to total impacts) and by impact category, such as energy, criteria pollutants, and other groups of metrics built into the assessment. Tables can be exported to Excel or text files and charts can be exported as images for use in reporting.

Wizard: '5 Evaluate Products'; Step: 13

Skip categories: Never

Comparing 1 p life cycle 'Slim_LC_EOLStand' with 1 p life cycle 'Garland_LC_EOLStand' and with 1 p life cycle 'Airtouch_LC_EOLStand'; Method: TRACI - United States National Average / characterization

Figure 7 Sample Chart-Based Reporting Output



No	Substance	Unit	Airtouch_UASS3042	Garland_GCD7236	Airtouch_UASS3042
1	additions	g	452	x	x
2	air	oz	108	18	6.76
3	alloys	g	208	x	77.8
4	aluminium scrap	kg	10.2	x	4.02
5	animal matter	mg	x	79.3	x
6	barrage water	kg	230	x	8.73
7	baryte	mg	952	108	45.2
8	bauxite	oz	144	0.0106	51.9
9	bentonite	mg	414	68.8	19.1
10	biomass	g	598	27.2	6.37
11	boron (in ore)	mg	185	x	x
12	calcined coke	oz	10.3	x	136
13	calcium sulphate	mg	40.5	7.21	2.04
14	cardboard	g	86	x	20.6
15	chromium (in ore)	g	0.0342	0.00115	11.4
16	chromium (ore)	g	x	x	21.9
17	clay	mg	10	1.3	0.43
18	coal	g	359	x	26.3
19	coal ETH	oz	90.6	6.14	2.76
20	coal FAL	kg	8.85	44	15.6
21	copper (in ore)	mg	1.58	46.6	20.9
22	crude oil	g	157	118	24.3
23	crude oil ETH	oz	222	35.3	13.2
24	crude oil FAL	kg	4.1	21.6	8.49
25	crude oil IDEMAT	g	x	5.24	x
26	dolomite	g	167	538	595
27	energy (undef.)	MJ	2.05	0.48	9.1
28	energy from fossil	kWh	77.8	x	396
29	energy from hydro power	MJ	8.81	55.3	3.75

Figure 8 Partial View of Sample Table-Based Reporting Output

Both the chart and table based formats use the selected impact assessment profile, as sampled in Figure 6, to calculate impacts associated with the product as a whole. In Figure 8, the production of substances defined in the impact assessment profile is listed for three products, and the data can be reorganized by impact category, substance, and amount of impact. For example, in row 24 on Figure 8, the consumption of crude oil used throughout production is compared for three products. The second product consumes 21.6 kilograms as compared to 4.1 and 8.49 kilograms consumed by the first and third products. Using this data, developers can select and evaluate which product out of several options performs the best according to their criteria or identify areas of a product where major improvements to environmental performance are needed.

An additional reporting format is the "network" view of a product assembly, which visually displays the relative contribution of impacts from each component in the assembly. Two sample network views are shown in Figures 9 and 10: a basic product assembly in the former and a full product profile with materials, processes, and other elements included in the latter. This format is particularly valuable during product development when developers will often need to determine specific areas to focus their efforts in reducing total product impacts.

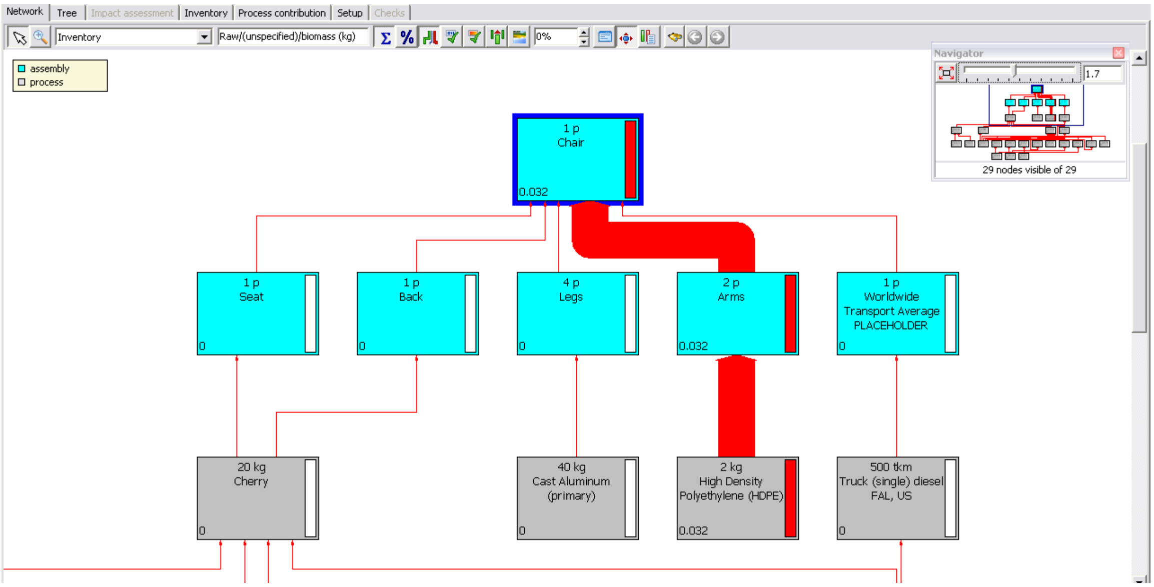


Figure 9 Partial View of Basic Product Assembly and Relative Impacts of Components

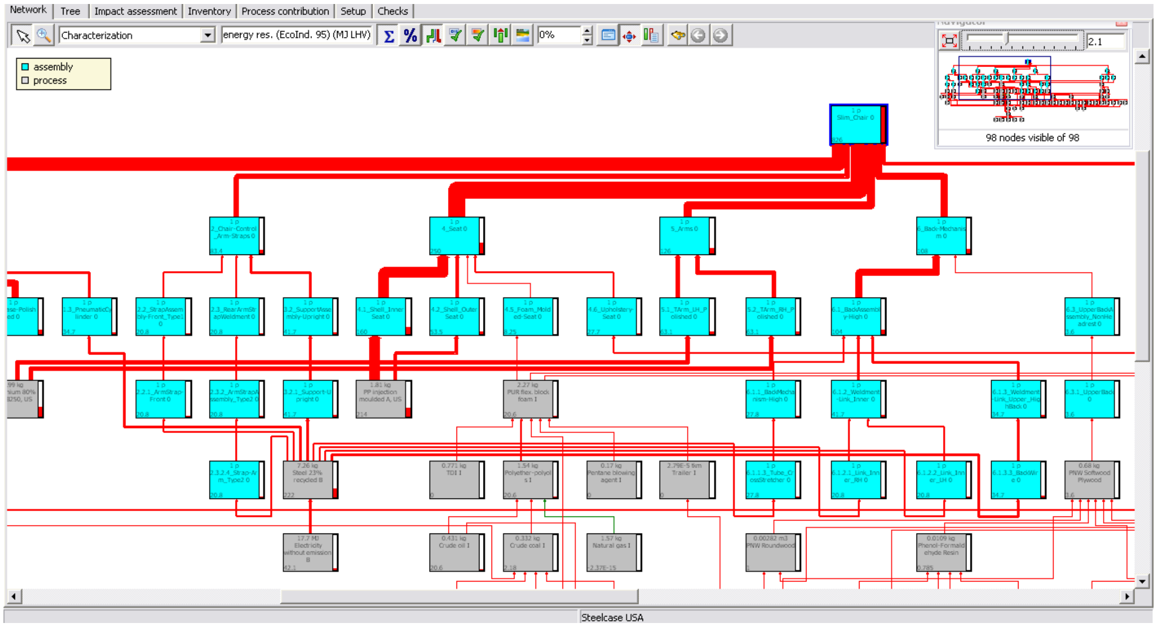


Figure 10 Partial View of Full Product Assembly and Relative Impacts of Components

While these graphical, table-based, and network formats provide a wealth of information, they are somewhat limited in visual flexibility and are particularly problematic when metrics are qualitative, binary, or otherwise coded in a non-continuous manner. For example, measures of recyclability beyond the percentage of material content that can be recycled, as discussed in Section 4.5, cannot be included. Ratings of materials as presenting “high”, “medium” or “low” impacts as used in Cradle-to-Cradle metrics and discussed in Section 4.4 are, at best, difficult to incorporate. Therefore, the SimaPro report formats do not produce the most visually usable results for certain Steelcase metrics and assessment frameworks. They are, however, well suited for the purpose of evaluating life cycle impacts across multiple categories which is a critical new category of analysis for Steelcase product developers.

4.2 Steelcase Impact Assessment Metrics and Frameworks

Steelcase uses a number of metrics and frameworks to evaluate product environmental impacts. The primary tools currently in use are described in Table 5.

Table 5 Current Steelcase Environmental Performance Frameworks and Metrics

Current Metric / Framework	Purpose of Measurement
CO_2 equivalent (CO_2e)	CO_2e compares the impacts of various greenhouse gas emissions based upon their global warming potential. The CO_2e for a specific greenhouse gas is derived by multiplying the tons of that gas by its associated global warming potential[64]. The total of CO_2e for all relevant greenhouse gases is then compiled for a total CO_2e measure. Emissions of CO_2 and other greenhouse gases result from energy use and other processes used to produce materials and final products. Steelcase sets internal goals for CO_2e performance on a per product basis. This metric is also part of the full Life Cycle Analysis assessment framework.
Cradle-to-Cradle Certification (C2C)	C2C is an external certification program that covers many environmental impacts. Most relevant to WELE is its ranking of materials based in part on their toxicity impacts. Each material is classified as Red, Orange, Yellow, or Green depending on toxicity risk, with Red materials prohibited from use and Green materials strongly preferred due to their minimal toxicity concerns. Steelcase aims to exclude all Red materials from its products.
Recyclability	Steelcase sets internal goals for product recyclability at the end of life. Distinct from the recycled content going into a product, recyclability must take into account the process of disassembling a product and the likelihood of each material being recycled based on current recycling capabilities.
ISO 14040 compliant Life Cycle Analysis (LCA)	Conducted only after a product is fully designed, Steelcase reviews products according to ISO Standard 14040 for Life Cycle Analysis and makes selected environmental performance results publicly available through Environmental Product Declarations (EPDs).

The introduction of full life cycle analysis frameworks into early stage product development is a valuable advantage of the WELE tool. However, it must be emphasized that use of these frameworks during product development is not meant to and indeed is not capable of meeting ISO 14040 standards required for public reporting of product impacts. Rather, it is intended to internally estimate impacts as the product moves through development.

---

[64] U.S. Environmental Protection Agency glossary: www.epa.gov/climatechange/glossary.html. Last accessed April 2008. Discussed in further detail in Section 4.3.

In addition, Steelcase's policies are continuing to change and the process of tool creation has raised questions regarding which specific metrics and targets should be used throughout product development. These policy questions are outside the scope of this research project, but they remain an important issue at Steelcase. SimaPro is structured so that new metrics and frameworks can be entered with relative ease and be applied immediately to existing and new product profiles. As Steelcase continues to define its most critical metrics, building these into the tool should be straightforward.

4.3 CO_2e

Steelcase uses CO_2 equivalent (CO_2e)[65] as the measure of a product's global warming potential. SimaPro is well suited to report on this metric as CO_2e is included in a number of broader calculations of life cycle impacts. Most generic materials and processes in the database include measures of CO_2 and other greenhouse gas emissions that can be evaluated by weighting them through the CO_2e metric. As discussed in Section 5.0, data can also be collected on Steelcase-specific materials or approximated from generic sources to gain a proxy measure of CO_2e.

In terms of report outputs, the bar chart (Figure 11) and table (Figure 12) formats are sufficient for reporting CO_2e of a single product or comparing CO_2e between products. As with other measurements, the network view (Figure 13) is also valuable in identifying the components and input materials/processes with the greatest impact in a single product.

---

[65] Carbon dioxide (CO_2) equivalent measures total output of greenhouse gases weighted by their relative impacts. For example, a unit of methane gas (CH_4) is estimated to have the same global warming potential as 23 units of CO_2 according to the International Panel on Climate Change's (IPCC) 2001 assessment. Due to its greater impacts per unit, a nitrous oxide (N_2O) unit is estimated to have the same impact as 296 units of CO_2. With total emissions of CH_4 and N_2O weighted by 23 and 296 respectively, these weighted values are added to total emissions of CO_2 to calculate CO_2 equivalent as a measure of total global warming potential. More information on this metric is available at www.ipcc.ch (last accessed April 2008).

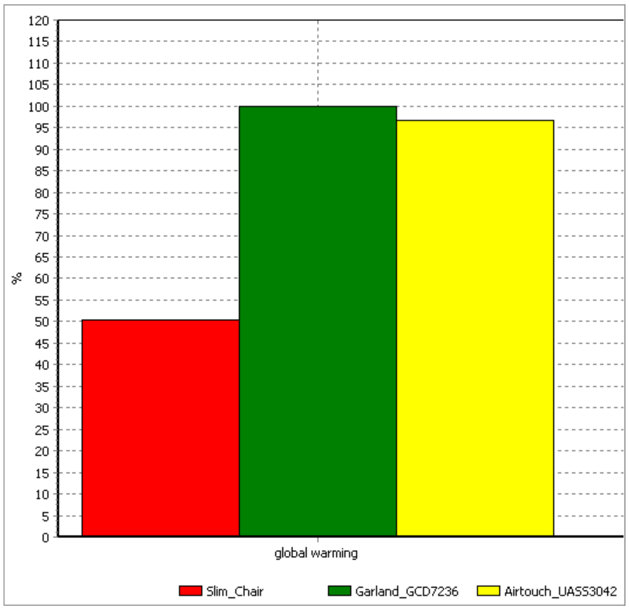
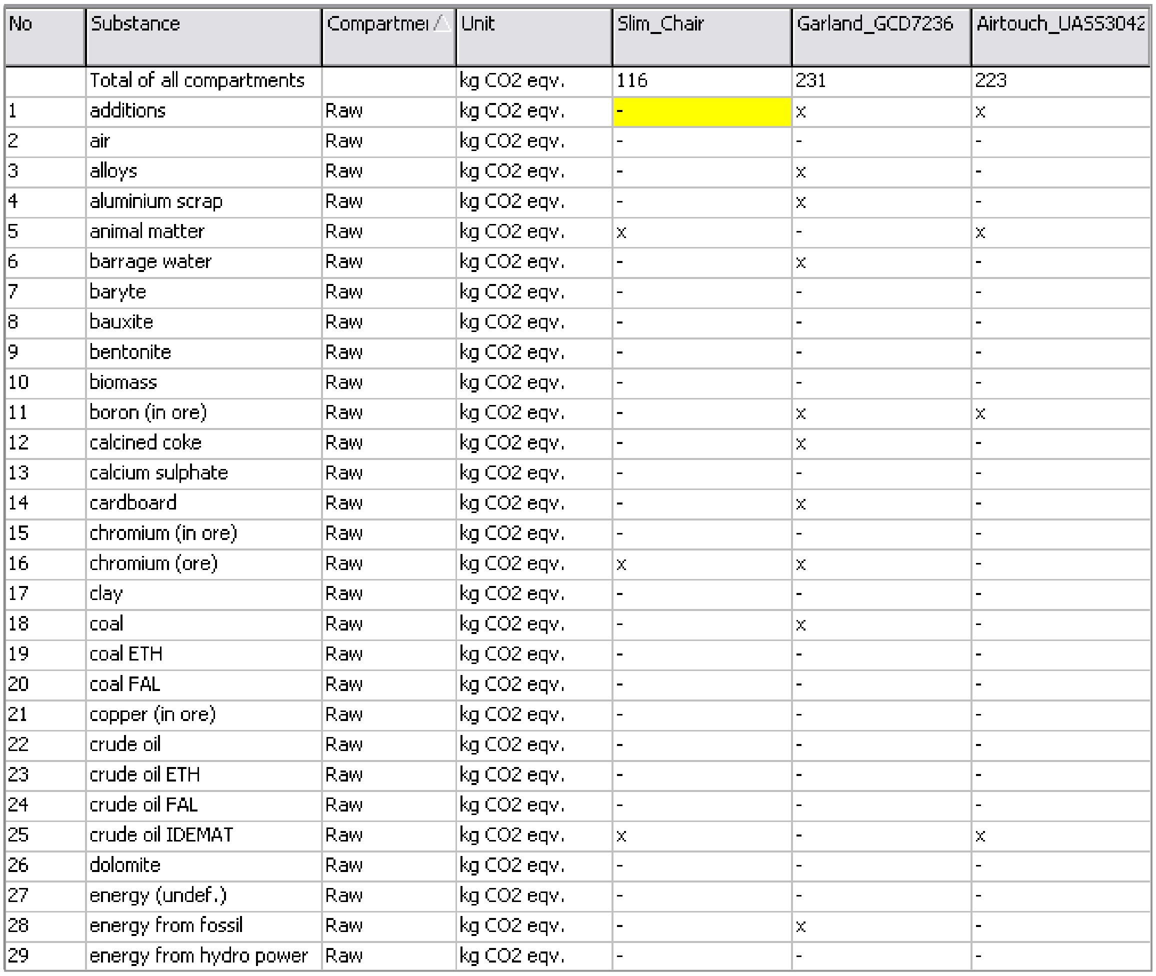


Figure 11 Sample Chart-Based CO₂e Comparison



No	Substance	Compartme △	Unit	Slim_Chair	Garland_GCD7236	Airtouch_UAS3042
	Total of all compartments		kg CO2 eqv.	116	231	223
1	additions	Raw	kg CO2 eqv.	-	x	x
2	air	Raw	kg CO2 eqv.	-	-	-
3	alloys	Raw	kg CO2 eqv.	-	x	-
4	aluminium scrap	Raw	kg CO2 eqv.	-	x	-
5	animal matter	Raw	kg CO2 eqv.	x	-	x
6	barrage water	Raw	kg CO2 eqv.	-	x	-
7	baryte	Raw	kg CO2 eqv.	-	-	-
8	bauxite	Raw	kg CO2 eqv.	-	-	-
9	bentonite	Raw	kg CO2 eqv.	-	-	-
10	biomass	Raw	kg CO2 eqv.	-	-	-
11	boron (in ore)	Raw	kg CO2 eqv.	-	x	x
12	calcined coke	Raw	kg CO2 eqv.	-	x	-
13	calcium sulphate	Raw	kg CO2 eqv.	-	-	-
14	cardboard	Raw	kg CO2 eqv.	-	x	-
15	chromium (in ore)	Raw	kg CO2 eqv.	-	-	-
16	chromium (ore)	Raw	kg CO2 eqv.	x	x	-
17	clay	Raw	kg CO2 eqv.	-	-	-
18	coal	Raw	kg CO2 eqv.	-	x	-
19	coal ETH	Raw	kg CO2 eqv.	-	-	-
20	coal FAL	Raw	kg CO2 eqv.	-	-	-
21	copper (in ore)	Raw	kg CO2 eqv.	-	-	-
22	crude oil	Raw	kg CO2 eqv.	-	-	-
23	crude oil ETH	Raw	kg CO2 eqv.	-	-	-
24	crude oil FAL	Raw	kg CO2 eqv.	-	-	-
25	crude oil IDEMAT	Raw	kg CO2 eqv.	x	-	x
26	dolomite	Raw	kg CO2 eqv.	-	-	-
27	energy (undef.)	Raw	kg CO2 eqv.	-	-	-
28	energy from fossil	Raw	kg CO2 eqv.	-	x	-
29	energy from hydro power	Raw	kg CO2 eqv.	-	-	-

Figure 12 Sample Table-Based CO₂e Comparison

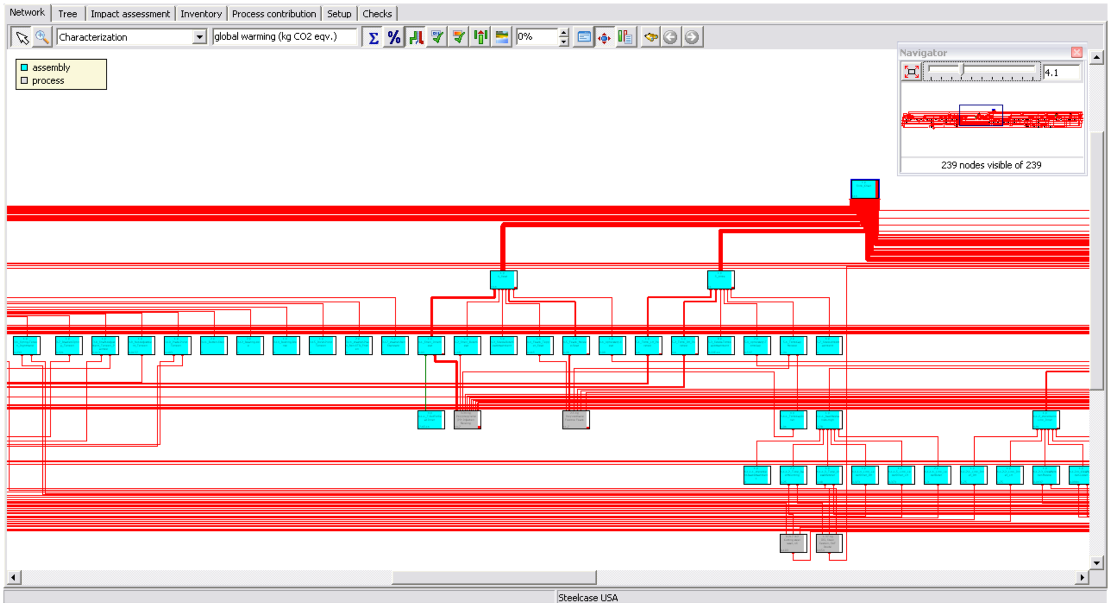


Figure 13 Sample Network View of CO_2e Contributions in a Single Product

4.4 Cradle to Cradle Certification

Cradle to Cradle Certification[66] is an environmental analysis method for materials developed and operated by McDonough Braungart Design Chemistry (MBDC). MBDC works with a variety of material suppliers who submit data to MBDC for evaluation, the results of which are then shared with downstream participants in the program.

Cradle to Cradle evaluates material and other product impacts using a variety of metrics including material toxicity, energy use, reutilization through recycling and other methods, water use, and social responsibility. Concerning toxicity in particular, materials are scored and classified as Red, Orange, Yellow, or Green. Materials classified as Red are generally prohibited from use at Steelcase while Yellow materials can be used if no appropriate substitute is available. Materials classified as Green have met all toxicity thresholds and are acceptable for use. The additional Orange classification is used for materials when insufficient data prevents full analysis of toxicity impacts. In addition, products as a whole can receive certification as Cradle to Cradle Gold, Silver, and Bronze if they incorporate efforts to use acceptable materials and meet the criteria for other environmental impact areas. A sample assessment of materials is shown in Figure 14.

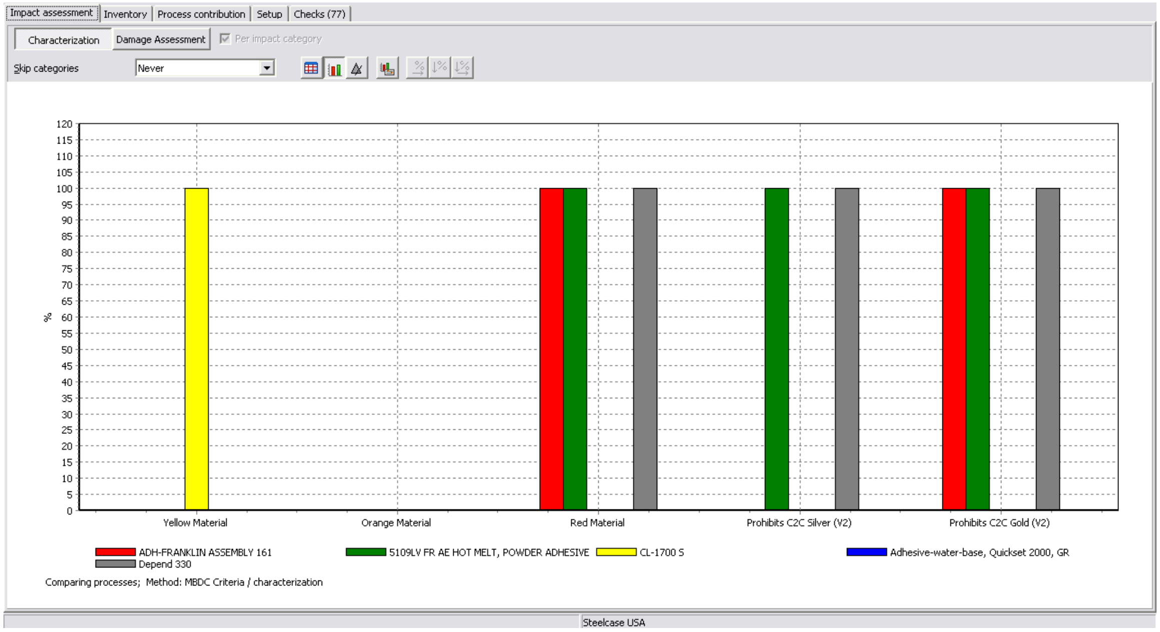
---

[66] *MBDC Cradle to Cradle Certification Program*. McDonough Braungart Design Chemistry. Charlottesville, VA. 2007. Available at www.mbdc.com/docs/Outline_CertificationV2_Final.pdf. Last accessed April, 2008.

Material	Assessment	C2C Gold	C2C Silver	Comments
Adhesive 1	RED	NO	Y	Contains two minor problematic ingredients
Adhesive 2	RED	NO	Y	Contains one minor problematic ingredient WILL BE YELLOW SOON
Adhesive 3	RED	Y	Y	Contains one minor problematic ingredient
Metal 1	GREEN	Y	Y	
Metal 2	YELLOW	Y	Y	Contains minor amounts of moderately problematic elements
Metal 3	YELLOW	Y	Y	Contains minor amounts of moderately problematic elements
Metal 4	GREEN	Y	Y	

Figure 14 Sample Cradle to Cradle Material Evaluations[67]

Integrating these metrics into the SimaPro format is possible but challenging due to the non-numerical ranking of materials. Because SimaPro requires numerically based reporting, an artificial binary ranking of 0 or 1 is used to categorize materials as Red, Yellow, Orange or Green (e.g. if a material is "Red", the "Red" box in its material profile is numbered "1" instead of "0") and the Gold or Silver certification level to which they contribute. This allows reporting on Cradle to Cradle performance but results in somewhat awkward visual displays that lose the benefit of rating materials based on a color system. A sample display comparing four different materials (adhesives) is shown in Figure 15.



Skip categories: Never

Comparing processes; Method: MBDC Criteria / characterization

Figure 15 Sample Chart-Based Cradle to Cradle Comparison

---

[67] Material names and categories removed due to proprietary nature.

An additional workaround was explored using SimaPro's internal color scheme for data quality in which materials with low data quality are highlighted as red and those with moderate data concerns are highlighted as yellow. However, the different use of this system and the indicators reflected by Cradle to Cradle's color coding would create significant confusion, and the SimaPro color coding is not designed to be reported through the wizards process used for WELE.

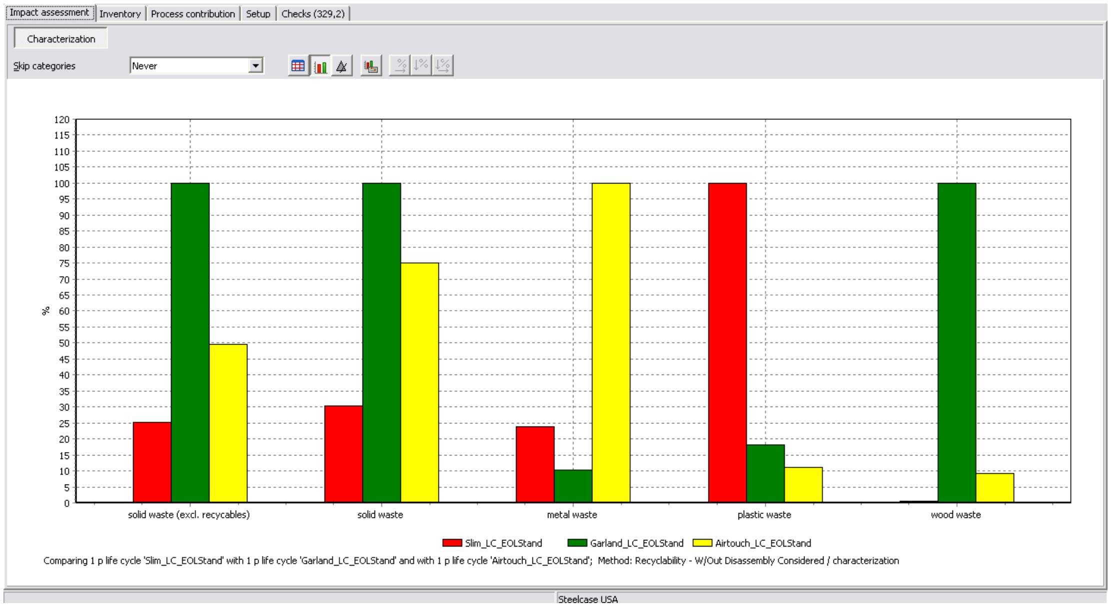
While the current "0, 1" approach is moderately sufficient in at least reporting the results of Cradle to Cradle performance, it is far from an ideal visual format. Similar to some of the other usability issues encountered during testing, this points to a potential need for a temporary Excel or other external interface until SimaPro coding is altered to allow different reporting methods.

4.5 Recyclability

The recyclability metric is driven in part by the individual recycling potential of materials when the product is disposed, based on generic recycling rates for individual materials. It is also driven by product assembly decisions and the potential for disassembly and material separation at the end of life that determines the viability of recycling materials in practice. While the former can be measured with relative consistency in SimaPro, the latter is a qualitative measure and needs to be addressed as such, though there is a general proxy measure that can be included in product profiles built through WELE.

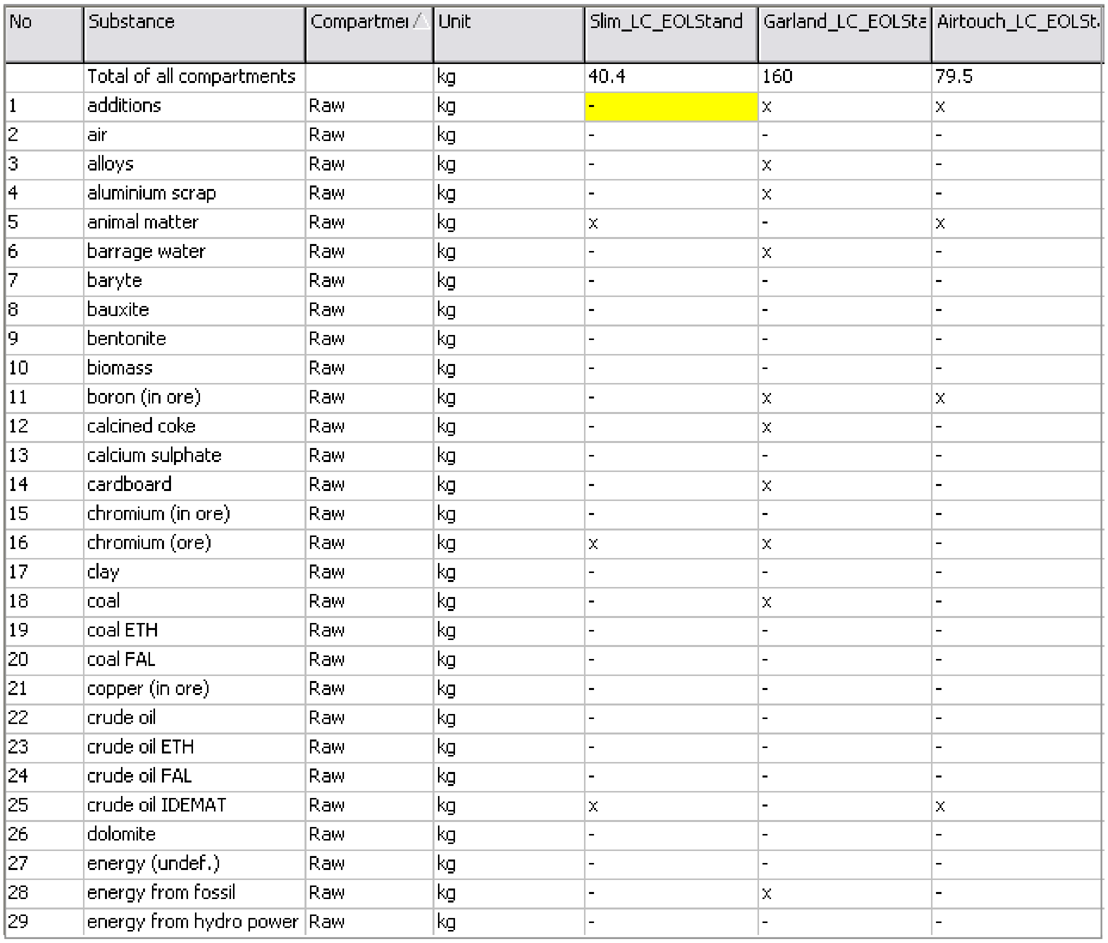
In SimaPro, the recyclability of individual materials feeding into a product assembly is measured through an end of life profile assigned to the product, which is then evaluated through an assessment framework that accounts for estimated generic rates of recycling as well as remaining materials that are disposed of as solid waste. Every product profile created through WELE is assigned a generic end of life profile that assumes average recycling rates unless otherwise specified. However, it is possible to assign end of life profiles representing higher or lower rates of recycling for various materials – a change that could be influenced by design for disassembly efforts. Therefore, if developers have focused on this aspect of recyclability they can represent it in their product evaluations.

The output of this analysis is reportable within the SimaPro bar chart (Figure 16) and table based (Figure 17) visual structures. These figures show recyclability comparisons for three different Steelcase products. Impacts are represented as solid waste in a variety of categories, and products with higher recyclability performance will have lower solid waste outputs in reporting. The network format (Figure 18) for individual products also demonstrates the material flows at the end of life and can be used to trace major solid waste contributors back to individual components of the product.



Comparing 1 p life cycle 'Slim_LC_EOLStand' with 1 p life cycle 'Garland_LC_EOLStand' and with 1 p life cycle 'Airtouch_LC_EOLStand'; Method: Recyclability - W/Out Disassembly Considered / characterization

Figure 16 Sample Chart-Based Recyclability Comparison Measuring Solid Waste



No	Substance	Compartmer /	Unit	Slim_LC_EOLStand	Garland_LC_EOLSta	Airtouch_LC_EOLSt
	Total of all compartments		kg	40.4	160	79.5
1	additions	Raw	kg	-	x	x
2	air	Raw	kg	-	-	-
3	alloys	Raw	kg	-	x	-
4	aluminium scrap	Raw	kg	-	x	-
5	animal matter	Raw	kg	x	-	x
6	barrage water	Raw	kg	-	x	-
7	baryte	Raw	kg	-	-	-
8	bauxite	Raw	kg	-	-	-
9	bentonite	Raw	kg	-	-	-
10	biomass	Raw	kg	-	-	-
11	boron (in ore)	Raw	kg	-	x	x
12	calcined coke	Raw	kg	-	x	-
13	calcium sulphate	Raw	kg	-	-	-
14	cardboard	Raw	kg	-	x	-
15	chromium (in ore)	Raw	kg	-	-	-
16	chromium (ore)	Raw	kg	x	x	-
17	clay	Raw	kg	-	-	-
18	coal	Raw	kg	-	x	-
19	coal ETH	Raw	kg	-	-	-
20	coal FAL	Raw	kg	-	-	-
21	copper (in ore)	Raw	kg	-	-	-
22	crude oil	Raw	kg	-	-	-
23	crude oil ETH	Raw	kg	-	-	-
24	crude oil FAL	Raw	kg	-	-	-
25	crude oil IDEMAT	Raw	kg	x	-	x
26	dolomite	Raw	kg	-	-	-
27	energy (undef.)	Raw	kg	-	-	-
28	energy from fossil	Raw	kg	-	x	-
29	energy from hydro power	Raw	kg	-	-	-

Figure 17 Sample Table-Based Recyclability Comparison Measuring Solid Waste

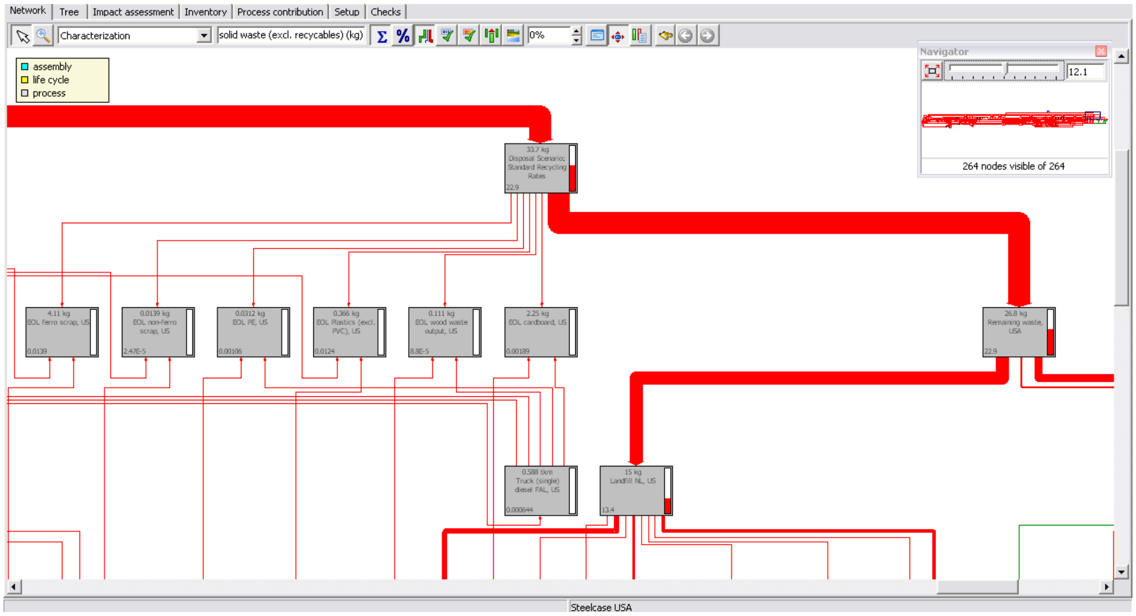


Figure 18 Network View of a Product Showing Return of Materials at End of Life

While recyclability depends in part on the product's disassembly potential, feasibility of individual material recycling can accurately be reflected on a full product basis through the reporting features in SimaPro. In addition, disassembly can also be reflected if not evaluated when modeling products through WELE by selecting different end of life scenarios. It remains critical that developers are aware of this distinction and continue to address disassembly needs during product development.

4.6 Multi-Criteria Life Cycle Analysis

The newest area for Steelcase's product developers is evaluation of products based on total life cycle impacts. This analysis is already performed by environmental experts at the end of product design in order to provide public information in compliance with ISO Standard 14040. However, the expectation that developers will estimate full life cycle impacts throughout the development process is a new requirement and a primary driver of the development of WELE.

Of the assessment frameworks and metrics discussed here, broad reaching life cycle analysis is actually the simplest to perform through WELE because this type of broad analysis is a primary function and strength of SimaPro. Several life cycle assessment frameworks are available in the standard software, the most relevant of which are TRACI[68] and EDIP[69].

---

[68] TRACI is the Tool for the Reduction and Assessment of Chemical and other Environmental Impacts and was developed by the U.S. Environmental Protection Agency to characterize a variety of environmental impacts resulting from industrial processes. More information is available at www.epa.gov/nrmrl/std/sab/traci/. Last accessed April, 2008.

TRACI is the de facto life cycle analysis characterization framework in the U.S. and EDIP serves the same purpose in Denmark and several other areas of Europe. Both use a variety of criteria to measure and weight the environmental impacts of materials across impact categories. However, because they were developed based on different national and regional policies, the criteria and weighting factors differ significantly in some areas.

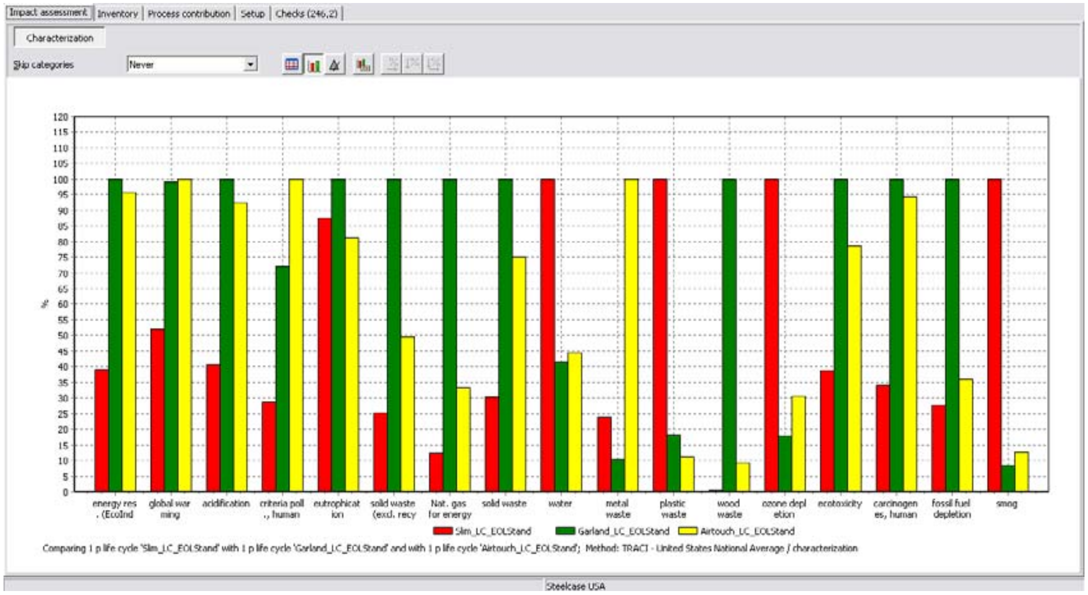
Steelcase is currently evaluating ways to combine or otherwise use these methods in parallel in order to ensure standard evaluation procedures across international groups. Because such an evaluation is out of scope for this research project, TRACI and EDIP have been included as separate reporting options in the current version of WELE. A combined or otherwise modified framework or set of metrics can be added with relative ease once Steelcase defines its policy on this issue.

Using TRACI or EDIP, SimaPro can calculate total product impacts based on the materials and processes feeding into the product and the variety of environmental metrics and weights built into each assessment framework. The TRACI characterization framework in SimaPro groups impacts into energy resources, global warming potential, acidification potential, criteria pollutants, eutrophication, solid waste categories, ozone depletion, ecotoxicity, carcinogens, fossil fuel depletion, and smog. The EDIP assessment framework groups impacts into global warming, ozone potential, acidification, eutrophication, smog, ecotoxicity, human toxicity, solid waste categories, and resource consumption.

Both can be displayed within the bar chart (Figure 19) and table based (Figure 20) approaches as well as the network view (Figure 21) for single products.

---

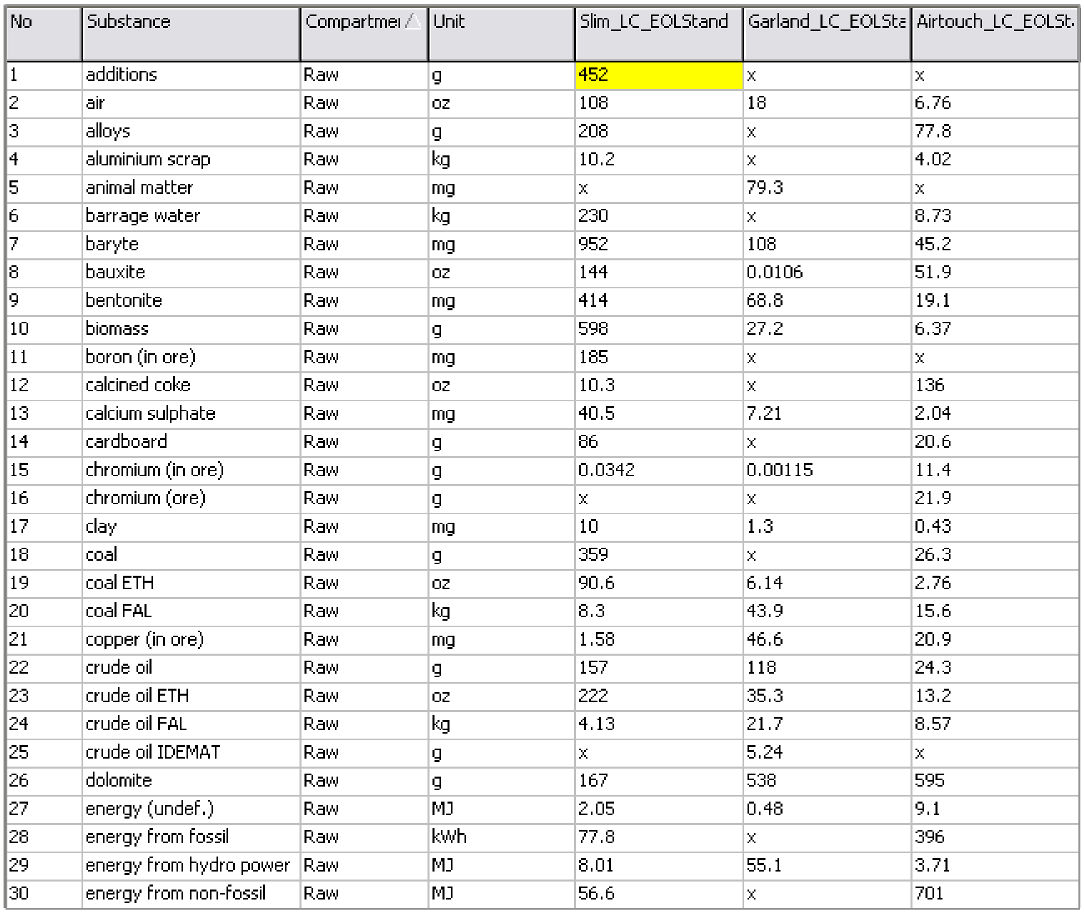
[69] EDIP stands for Environmental Development of Industrial Products and was developed by the Danish Environmental Protection Agency. Similar to TRACI in its assessment and weighting of various impacts, though based on different criteria, EDIP is widely used throughout Europe as a life cycle assessment framework. More information is available at www.lca-center.dk/cms/site.aspx?p=1378. Last accessed April, 2008.



Skip categories: Never

Comparing 1 p life cycle 'Slim_LC_EOLStand' with 1 p life cycle 'Garland_LC_EOLStand' and with 1 p life cycle 'Airtouch_LC_EOLStand'; Method: TRACI - United States National Average / characterization

Figure 19 Sample Chart-Based Comparison of Life Cycle Impacts Using TRACI



No	Substance	Compartmei	Unit	Slim_LC_EOLStand	Garland_LC_EOLSta	Airtouch_LC_EOLSt
1	additions	Raw	g	452	x	x
2	air	Raw	oz	108	18	6.76
3	alloys	Raw	g	208	x	77.8
4	aluminium scrap	Raw	kg	10.2	x	4.02
5	animal matter	Raw	mg	x	79.3	x
6	barrage water	Raw	kg	230	x	8.73
7	baryte	Raw	mg	952	108	45.2
8	bauxite	Raw	oz	144	0.0106	51.9
9	bentonite	Raw	mg	414	68.8	19.1
10	biomass	Raw	g	598	27.2	6.37
11	boron (in ore)	Raw	mg	185	x	x
12	calcined coke	Raw	oz	10.3	x	136
13	calcium sulphate	Raw	mg	40.5	7.21	2.04
14	cardboard	Raw	g	86	x	20.6
15	chromium (in ore)	Raw	g	0.0342	0.00115	11.4
16	chromium (ore)	Raw	g	x	x	21.9
17	clay	Raw	mg	10	1.3	0.43
18	coal	Raw	g	359	x	26.3
19	coal ETH	Raw	oz	90.6	6.14	2.76
20	coal FAL	Raw	kg	8.3	43.9	15.6
21	copper (in ore)	Raw	mg	1.58	46.6	20.9
22	crude oil	Raw	g	157	118	24.3
23	crude oil ETH	Raw	oz	222	35.3	13.2
24	crude oil FAL	Raw	kg	4.13	21.7	8.57
25	crude oil IDEMAT	Raw	g	x	5.24	x
26	dolomite	Raw	g	167	538	595
27	energy (undef.)	Raw	MJ	2.05	0.48	9.1
28	energy from fossil	Raw	kWh	77.8	x	396
29	energy from hydro power	Raw	MJ	8.01	55.1	3.71
30	energy from non-fossil	Raw	MJ	56.6	x	701

Figure 20 Sample Table Based Comparison of Life Cycle Impacts Using TRACI

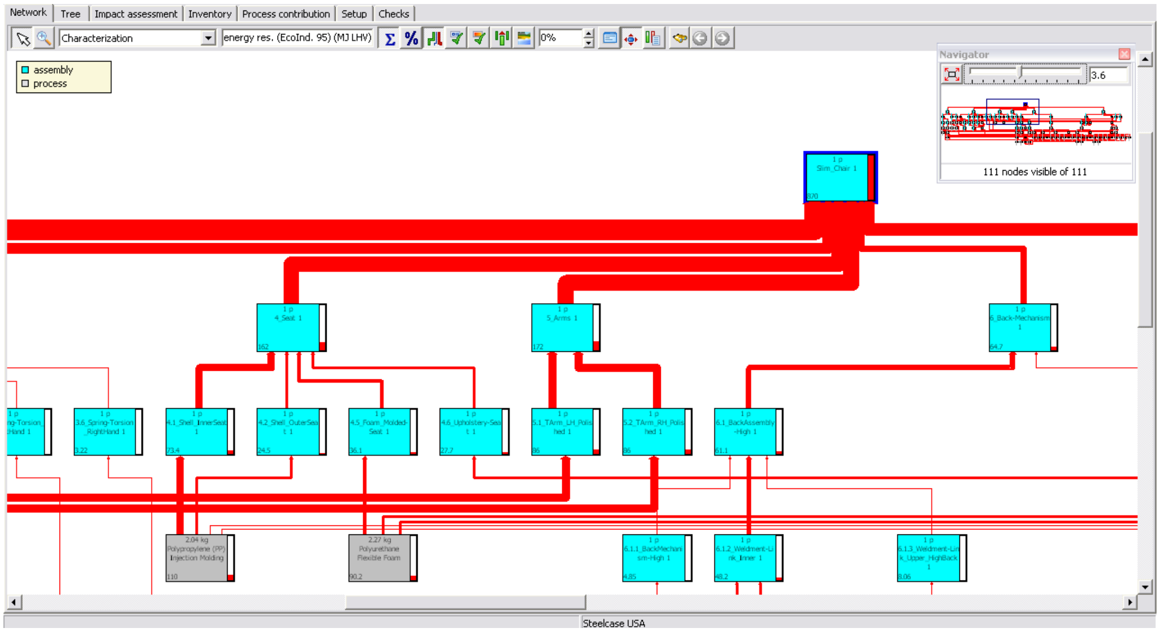


Figure 21 Sample Network View of Environmental Impacts Using TRACI

Reflecting life cycle impacts across multiple impact categories is therefore highly achievable within the tool, and proves to be one of the more valuable presentations available to product developers. While the ongoing discussion of TRACI and EDIP frameworks needs to be resolved, the use of either is feasible regardless of the outcome of this discussion.

4.7 Future Assessment Framework and Metric Integration

Additional work is needed to bring reporting to a fully functional level. In particular, an approach to integrating Cradle to Cradle metrics needs to be resolved either through SimaPro coding changes or through an interim substitute at Steelcase. The resolution of TRACI and EDIP is also needed, though in the interim U.S. product developers – the current primary users of the tool – can rely on TRACI as the primary characterization framework.

An additional policy area that needs to be resolved and ultimately integrated is the levels of performance required of products in each category of evaluation. While comparative analyses can be conducted in each impact category, there are often tradeoffs between impacts, with one product option performing better in a first respect and a second product option performing better in a second (e.g. the first contributing less to global warming and the second contributing less to ozone depletion). Setting clear targets for product performance, such as maximum levels of CO_2e for a product, is an additional ongoing discussion at Steelcase. Identification of these targets for each impact category will be essential for the long term usability of the tool.

5.0 Data Development

Primary data on the impacts of materials, processes, transportation, use and end of life all serve as inputs into a product profile and ultimately contribute to the reported impacts of the product. Therefore, the accuracy of WELE relies significantly on the accuracy of input data in these categories. This accuracy is best achieved by measuring the impacts of a company's own operations and supply chain as environmental impacts can vary greatly across companies and among suppliers. However, the time and costs required to collect data and maintain it over time are significant.

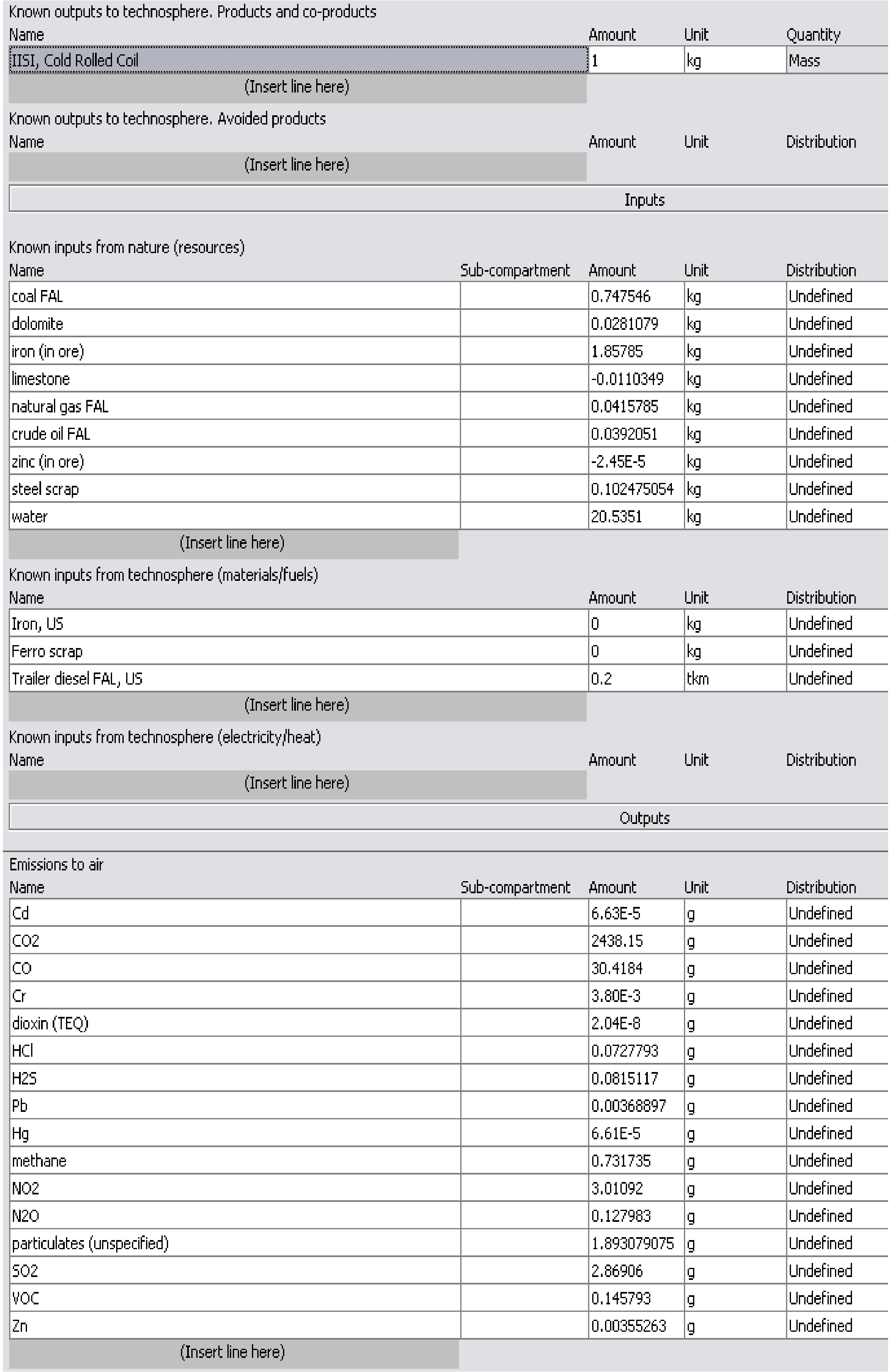
SimaPro provides a solid foundation in generic industry data that alleviates some of the need for this effort. But to ensure that product developers are on the right path to achieving results that match final life cycle assessments by environmental experts, some degree of Steelcase-specific data is highly desirable as long as it can be collected with a high degree of certainty about accuracy and requires minimal investment.

Therefore, part of this research focuses on where Steelcase-specific data could be most useful in product development and how it can be collected and ultimately integrated into WELE. While much work will need to be done to implement these recommendations, there is a significant opportunity to integrate the suggested data collection and tracking methods into a broader, company-wide IT initiative in development at Steelcase.

5.1 SimaPro Storage of Profiles

SimaPro uses standard forms to store individual profiles for materials, processes, transportation modes, and end of life scenarios. Use phase impact profiles can also be created and stored as scenarios. Each profile includes the major inputs and outputs of the material and the range of environmental emissions to air, water, soil, and waste flows. It includes several additional categories for non-material emissions such as radiation and social/economic issues attributed to the material or other element. These profiles are then linked through WELE to a product profile and ultimately evaluated using one of the assessment frameworks discussed in Section 4.0.

SimaPro includes a variety of standard profiles for materials, processes, and other elements based on in-depth industry research from multiple sources. A sample profile is shown in Figure 22. In this profile, natural resource, material, and fuel inputs are calculated in the top sections and emissions to air, water, and solid waste are calculated below, typically on a weight basis. These standard profiles can generally be taken as valid approximations of impacts when combined in a product profile. However, when a company is focused on evaluating specific impacts of its own processes and material selections, and particularly when a company has made efforts to improve environmental performance beyond generic industry performance, true impacts can be quite different.



Known outputs to technosphere. Products and co-products

Name	Amount	Unit	Quantity
IISI, Cold Rolled Coil	1	kg	Mass

(Insert line here)

Known outputs to technosphere. Avoided products

Name	Amount	Unit	Distribution

(Insert line here)

Inputs

Known inputs from nature (resources)

Name	Sub-compartment	Amount	Unit	Distribution
coal FAL		0.747546	kg	Undefined
dolomite		0.0281079	kg	Undefined
iron (in ore)		1.85785	kg	Undefined
limestone		-0.0110349	kg	Undefined
natural gas FAL		0.0415785	kg	Undefined
crude oil FAL		0.0392051	kg	Undefined
zinc (in ore)		-2.45E-5	kg	Undefined
steel scrap		0.102475054	kg	Undefined
water		20.5351	kg	Undefined

(Insert line here)

Known inputs from technosphere (materials/fuels)

Name	Amount	Unit	Distribution
Iron, US	0	kg	Undefined
Ferro scrap	0	kg	Undefined
Trailer diesel FAL, US	0.2	tkm	Undefined

(Insert line here)

Known inputs from technosphere (electricity/heat)

Name	Amount	Unit	Distribution

(Insert line here)

Outputs

Emissions to air

Name	Sub-compartment	Amount	Unit	Distribution
Cd		6.63E-5	g	Undefined
CO2		2438.15	g	Undefined
CO		30.4184	g	Undefined
Cr		3.80E-3	g	Undefined
dioxin (TEQ)		2.04E-8	g	Undefined
HCl		0.0727793	g	Undefined
H2S		0.0815117	g	Undefined
Pb		0.00368897	g	Undefined
Hg		6.61E-5	g	Undefined
methane		0.731735	g	Undefined
NO2		3.01092	g	Undefined
N2O		0.127983	g	Undefined
particulates (unspecified)		1.893079075	g	Undefined
SO2		2.86906	g	Undefined
VOC		0.145793	g	Undefined
Zn		0.00355263	g	Undefined

(Insert line here)

Figure 22 Partial View of Material Profile from SimaPro

5.2 Generic versus Steelcase-Specific Data

Generic profile data in SimaPro uses industry averages or representative individual company research to estimate the impacts of a material or process. The approaches to evaluating inputs and emissions for generic profiles can differ. This fact, compounded with the fact that some companies, like Steelcase, outperform industry averages in some aspects of environmental performance, limits the potential for deriving accurate results from existing data.

At the same time, there is a need for generic data in the product development process. Particularly in Phases 0, 1, and 2, Steelcase-specific materials and processes often cannot be known because specific process and supplier selections do not typically occur until Phase 3. Therefore, a mix of generic and Steelcase-specific data is desired in WELE.

Based on discussions with product developers in Grand Rapids, assumptions about the need for generic versus Steelcase-specific data at each product development stage are outlined in Table 6.

Table 6 Generic vs. Steelcase-Specific Data Needs during Product Development

Data Needs	Materials	Processes
Stage 0 (Concept)	Generic data in SimaPro	Generic data in SimaPro
Stage 1 (Design)	Specific (supplier average)	Generic data in SimaPro
Stage 2 (Engineering)	Specific (single supplier)	Specific (Steelcase process)
Stage 3 (Process)	Specific (single supplier)	Specific (Steelcase process)

Stage 0 Data Needs

- Material profiles based on generic data
- Supplier transportation built into material profiles
- Process profiles based on generic data
- Steelcase transportation based on global average distribution distances

Stage 1 Data Needs

- Material profiles based on averages of Steelcase supplier impacts by material category (e.g. steel versus aluminum)
- Supplier transportation built into average Steelcase material profiles
- Process profiles based on generic data
- Steelcase transportation based on regional average distribution distances

Stage 2 Data Needs

- Material profiles available for individual suppliers as well as average profiles
- Supplier transportation built into individual and average material profiles
- Process profiles based on Steelcase average impacts, with energy and other critical impacts allocated on a per process basis
- Steelcase transportation based on regional average distribution distances

Stage 3 Data Needs

- Material profiles available for individual suppliers as well as average profiles
- Supplier transportation built into individual and average material profiles
- Process profiles based on Steelcase plant-specific impacts, with energy and other critical impacts allocated on a per process basis
- Steelcase transportation based on regional average distribution distances

The impacts of using generic versus Steelcase-specific data are explored in the case studies in Section 6.0. While Steelcase-specific data is essential for representing impacts with increasing accuracy as products are developed, it appears from these case studies that a combination of generic data in early stages and Steelcase-specific data in later stages achieves this goal with predictable increases in accuracy from stage to stage.

5.3 Data Collection Boundaries

Collecting and translating data into usable environmental profiles relies on the accessibility of primary data. As a company primarily focused on component building and assembly, Steelcase has limited transparency into the processes of material production upstream from its immediate suppliers and also has limited transparency downstream after its products are sold, used, and disposed of in various ways. This currently limits the degree to which Steelcase-specific data can be developed.

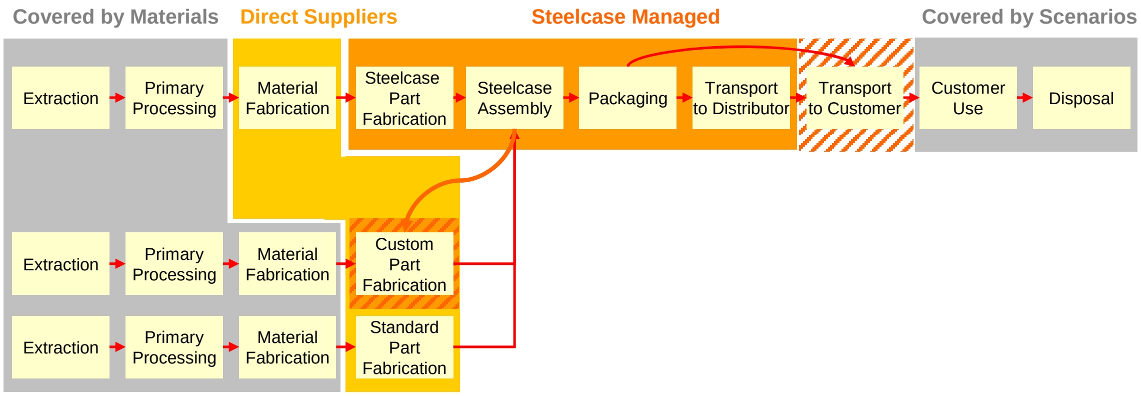


Figure 23 Data Collection Feasibility in the Life Cycle/Supply Chain

The areas that can potentially be addressed with specific data are direct supplier data ("Direct Suppliers" group in Figure 23) and internal Steelcase data ("Steelcase Managed" group in Figure 23). Material processing further upstream and the impacts from use and disposal are difficult for Steelcase to track but can be covered by generic material scenarios upon which supplier profiles can be based and by standard use and end of life profiles derived from generic data. Among immediate suppliers, distinctions must also be made between those that provide unmodified materials and those that provide standard or custom components because components produced outside Steelcase have multiple inputs that cannot always be captured by an individual material profile.

5.4 Data Collection Approach

Collecting data within this range of transparency is itself a challenge. A spectrum of potential approaches to internal data collection can bring increasing levels of accuracy in predicting environmental impacts, but greater accuracy necessitates more significant investments of time and resources. Collecting data outside company boundaries presents additional challenges in that immediate suppliers can be reluctant to share information that may expose internal cost structures or be otherwise confidential and may require investments in data collection that do not directly benefit internal operations. However, internally in both cases, there may be ways to collect proxy data at lower cost and lower risk.

For internal data collection on Steelcase assembly, packaging, and other operations, the spectrum of potential approaches are described in Table 7.

Table 7 Operation Modeling Options

Option	Accuracy Potential	Investment to Collect/Maintain
In-plant measurement of individual process consumption of energy, water, process materials	High	High
Combine existing Steelcase cost allocation methods for energy consumption with floor space allocations to individual processes as estimate of total impacts	Moderate	Significant
Combine existing process profiles in SimaPro with overhead cost allocations to each process added to each profile	Low to Moderate	Moderate
Create "product profile" representing typical impacts of aggregated processing used for a type of product (e.g. a standard "chair processes" profile based on study of existing lines)	Very Low	Low

There are clear tradeoffs between accuracy and investment among these options. A primary barrier to accuracy in some of the latter options is that energy, water use and expendable processing materials (chemicals and other materials consumed during processing but not part of the final product) that drive the environmental impacts of processes are typically tracked at the plant-wide level and are difficult to allocate to individual processes or products. Though environmental accounting methods for operational impacts exist[70], these also apply only to impacts tracked at the plant level.

Alternative direct measurement approaches are cost and time prohibitive on a company-wide scale. For example, prior work with Steelcase to evaluate specific impacts of three products[71] required plant visits to evaluate energy bills and measure the floor space used by each process step in order to approximate impacts. This approach cannot be replicated in multiple worldwide plants on a regular basis. One approach that may mitigate limitations in the future is the integration of Activity Based Costing – an effort that Steelcase and other companies are pursuing for cost accounting purposes. This method allocates inputs to a product based on its consumption of inputs rather than allocating overhead equally across all products. The result is a more accurate representation of the resources required for each product, and this would allow estimations of environmental impacts based on broader approaches to data management.

Collecting supplier data presents similar challenges in terms of the tradeoffs between accuracy and investment. It also presents the challenge of convincing suppliers that their own investment of time and resources provides them with some benefit and does not risk the exposure of operating cost structures. For example, Steelcase currently uses questionnaires and other informal supplier interactions to collect some environmental data. However, these efforts suffer from low response rates[72]. This appears to be a common problem; an external study on similar supplier interactions at the Steelcase competitor Herman Miller[73] indicates the need for developing some form of supplier incentive to participate in data sharing.

An incentive is also needed to ensure robust data in order to prevent ranking of suppliers based on the relatively minor impact category of supplier transportation. Assuming that most suppliers use similar modes of transportation to deliver materials and components, the transportation distance plays a significant role in calculating supplier transportation impacts. Therefore, if no other information is provided by a supplier on its internal impacts, the delivery distance plays a disproportionate role in measuring the supplier's environmental performance.

---

[70] www.epa.gov/oppt/library/pubs/archive/acct-archive/resources.htm Last accessed April, 2008.

[71] Dietz, Bernhard A. *Life Cycle Assessment of Office Furniture Products.* Center for Sustainable Systems, University of Michigan. Report No. CSS05-08. April 5, 2005.

[72] Steelcase supply chain representative. Rates of response are generally lower than 10%.

[73] Rossi, Mark et al. *Design for the Next Generation: Incorporating Cradle-to-Cradle Design into Herman Miller Products*. Journal of Industrial Ecology. Volume 10 Number 4. 2006. pp 193-210.

Beyond ensuring low investment and risk, a potential incentive to provide more robust data is a preferential system in which the suppliers that provide verifiable environmental performance data and meet certain performance levels determined by Steelcase are tagged as preferred suppliers. In a sense, the use of Cradle to Cradle certification is a proxy for this task when dealing with primary materials, though the only granular information that can be included consistently in a product profile are the toxicity measures of “Red”, “Yellow”, and “Green”. If these measures are supplemented with energy information and transportation distances, a slightly more robust picture of supplied material impacts can be derived. However, this certification does not apply to component suppliers that may need incentives to provide additional data.

The third area of impacts into which Steelcase has sufficient transparency is distribution and its related transportation impacts. This is a relatively simple area by comparison given that data on distributor and direct customer locations is typically tracked for sales purposes and Steelcase’s mode of distribution is almost exclusively truck based rather than using intermodal or multiple parallel transportation modes that would complicate environmental impact estimates. Therefore, creating global and regional averages for distribution impacts is a straightforward task.

Based on the potential for data transparency and consideration of investment requirements, recommendations for each aspect of Steelcase-specific data are discussed below. A significant amount of implementation and testing is needed to verify these approaches; however, they serve as a critical starting point in determining the process of company-specific data collection and use.

5.5 Supplied Materials

In the case studies discussed in section 6.0, materials are the most significant sources of environmental impacts within a product assembly, and data accuracy is particularly critical in this respect. Impacts occur at every stage of material production from extraction of input materials through primary and final material processing. These impacts include energy use, material waste, expendable processing materials, and water use among a variety of other emissions to air, water, and soil.

Because Steelcase cannot have transparency back to the extraction stage and suppliers are unlikely to have insight into upstream impacts, generic profiles of these input materials must be used. In order to be usable within SimaPro across all assessment frameworks, the ideal data provided by a supplier would cover energy use, water use, and expendable processing materials above and beyond primary material inputs.

A range of options exists to collect varying degrees of this data. These are outlined in Table 8 from least to most specific.

Table 8 Options for Development of Material Supplier Profiles

Option	Accuracy
Use industry average data by material type as proxy for supplier profiles.	Low
Use Cradle to Cradle data as a proxy for direct supplier material impacts in combination with generic profiles used for supplier energy consumption per unit of material.	Low
Collect supplier data on plant-wide energy use as proxy for direct supplier impacts and allocating energy to a material unit based on total material output per plant. Generic profiles used for supplier energy consumption.	Moderate
Collect supplier data on plant-wide energy, water, and expendable processing material use and allocating each to a material unit based on total material output per plant. Generic profiles used for supplier material inputs.	High

Of the four, the first is lacking in specificity to the point that supplier profiles no longer provide value beyond the generic data available in SimaPro. The final two could potentially be achieved through supplier surveys and compilation of individual profiles. However, they raise the potential issue of invasiveness into supplier operations and would likely result in low response rates without some form of supplier incentive.

The use of Cradle to Cradle data in combination with generic energy data is beneficial in both protecting suppliers' operating information and providing a simple measure of impacts that is already in use at Steelcase. The downside of this approach is that the specific Cradle to Cradle data cannot be used to measure material contribution to total life cycle impacts (e.g. product energy consumption or global warming potential).

However, if Cradle to Cradle is used in parallel with the use of generic material profiles for broader life cycle assessment, this may ultimately provide the greatest degree of accuracy for minimal investment. Therefore, the use of generic material profiles as the basis for supplier materials with the addition of each supplier's Cradle to Cradle rating appears to be the most feasible approach. This approach is described in Table 9.

Table 9 Approach to Material Supplier Profiles

Recommended Approach to Material Supplier Profiles	
Primary Inputs	Generic material profiles and metrics from Cradle to Cradle certification.
Calculations	None required.
Individual Supplier Profile Content	Generic material profile used as basis for supplier material energy inputs and Cradle to Cradle certification level added as supplementary measure of overall supplier performance.
Average Supplier Profile Content	By material category, average of energy and global warming impacts combined with Cradle to Cradle results based on individual supplier profiles.

Once the Cradle to Cradle certification level is available, creating and maintaining a supplier specific profile can be managed with relative ease over time.

5.6 Standard Supplied Components

In addition to unprocessed materials, Steelcase purchases standard components (e.g. bolts and screws) from external suppliers. These are often minor elements in a product, but obtaining supplier performance information can help developers select preferred providers of frequently used standard components and measuring their impacts in a product assembly.

Similar to direct materials, component impacts come from upstream material content and processing to create the final component. A critical difference is that Cradle to Cradle certification is not designed to measure the combined impact of materials in a component and therefore cannot be used as a similar proxy in this case. The range of options for varying degrees of data is outlined in Table 10 from least to most specific.

Table 10 Options for Development of Component Supplier Profiles

Option	Accuracy
Use industry average data by material type as proxy for supplier profiles.	Low
Collect supplier data on plant-wide energy use as proxy for direct supplier impacts and allocating energy to a material unit based on total material output per plant. Generic profiles used for supplier material inputs.	Moderate
Collect supplier data on plant-wide energy, water, and expendable processing material use and allocate each to an average material unit (e.g. bolt or screw) based on total material output per plant. Generic profiles used for supplier material inputs.	High

The second option of measuring supplier energy use on a per component basis is the least invasive approach from a supplier's perspective and also the most easily tracked on a plant-wide basis. Suppliers can also internally calculate the material unit allocation of energy use without revealing critical operating data to Steelcase.

An additional tracking option for standard component suppliers with advanced environmental accounting would be to provide a compilation of Cradle to Cradle certification for their input materials. This would provide a similar level of impact data to that provided by direct material suppliers. This approach is described in Table 11.

Table 11 Approach to Standard Component Supplier Profiles

Recommended Approach to Standard Component Supplier Profiles	
Primary Inputs	List of input materials and available Cradle to Cradle certification performance for these materials; energy per component allocation for supplier processes.
Calculations	None required.
Individual Supplier Profile Content	Component profile using generic material profiles with Cradle to Cradle certification levels added as inputs to the component. Energy use per component added as a process to the profile.
Average Supplier Profile Content	By component category, average of impacts based on individual supplier profiles.

While accommodating the need to protect proprietary supplier data, this approach still requires effort on the supplier's part to provide energy and Cradle to Cradle certification data. In these cases, an incentive from Steelcase such as preferred provider status will likely be essential to ensure a sufficient response rate.

5.7 Custom Supplied Components

While Steelcase produces some components in-house, a variety of product elements created by internal product developers are outsourced to other suppliers in addition to standard components. These custom components are distinct in that Steelcase has greater transparency into the material inputs and general processes needed for their production. However, there remains a lack of transparency into suppliers' actual impacts during processing and these impacts are difficult to estimate until the product and relevant components have been fully designed.

Therefore, this is an area where Steelcase's internal process estimates must be used as proxies for external supplier processing. This risks some loss of accuracy as external suppliers will have different impacts than Steelcase. However, it appears to be the closest feasible approximation of the potential impacts from outsourced components.

5.8 Supplier Transportation

All Steelcase interactions with suppliers of materials, standard components, and custom components require transportation that results in additional environmental impacts. The primary impacts of transportation are fuel consumption and air emissions, which vary across different transportation modes and can be significant over long distances. While contributing less to total impacts than materials and processing, transportation needs to be included in supplier profiles to accurately reflect impacts.

A range of options are possible in measuring supplier transportation impacts. These are outlined in Table 12 from least to most specific.

Table 12 Options for Development of Supplier Transportation Profiles

Option	Accuracy
Use estimate of average supplier travel distance and combination of estimated transportation modes across all suppliers.	Low
Use average travel distance for each supplier based on typical or average plant source for Steelcase inputs and combination of estimated transportation modes across all suppliers.	Moderate
Combine average travel distance with supplier information on specific transportation modes and proportions of use in travel distance (e.g. percent distance traveled by ship, rail, and truck transportation).	Moderate
Collect plant-specific information from individual suppliers and combine with supplier information on specific transportation modes and proportions of use in travel distance.	Highest

While soliciting supplier information on modes of transportation may be feasible, it is not apparent that this provides any significant benefits compared to the effort required. Requiring suppliers to provide plant-specific distances rather than a typical sourcing location also adds data needs that suppliers may not be able to fulfill. This latter approach also gets to a level of detail on sourcing decisions that will not be made during the product development process.

Therefore, the ideal approach is to use existing Steelcase information on suppliers to determine a typical or average plant location for the supplier to determine an average transportation distance and to assume a standard combination of transportation modes to calculate impacts. The only challenge with this approach is the use of local distributors that represent far flung suppliers. Steelcase in Grand Rapids uses a number of locally based companies that provide materials and components from a variety of suppliers. Steelcase only has access to the local addresses of these distributors, resulting in a lack of transparency on supplier transportation for some inputs. Steelcase would need to work with these companies to acquire average or detailed information on transportation one step upstream in order to gain accurate measures of distances.

Because each transportation profile will be associated with a single supplier, integrating transportation impacts into the SimaPro profile of a supplied material or component makes sense from a data management perspective and from the perspective of the product developers who would benefit from seeing all supplier impacts in one profile. This approach is described in Table 13.

Table 13 Approach to Supplier Transportation Profiles

Recommended Approach to Supplier Transportation Element of Supplier Profiles	
Primary Inputs	Average supplier distance based on internal Steelcase data and average proportion of transportation modes used in conveying materials and components to Steelcase.
Calculations	Split distance traveled into distance allocated to each mode of transportation (multiply by percent of distance traveled via each mode of transportation).
Individual Supplier Profile Content	Distances for each mode of travel included in each material, standard component, and custom component supplier profile.
Average Supplier Profile Content	Average supplier profiles include transportation distances for each mode of travel based on individual supplier profiles.

The time required on Steelcase's end to integrate transportation impacts into each supplier profile can be mitigated by managing supplier data outside of SimaPro and linking it to profiles within SimaPro through a COM interface approach, compatible with Excel, Access, and other COM-based software.

5.9 Steelcase Processes

Operational impacts arise from the processing of materials and components to create final products as well as overhead inputs at the plant level. These inputs include the use of energy, water, and expendable processing materials and result in a variety of impacts to air, water, soil, and waste streams.

Processes managed by Steelcase present a different opportunity for data collection as processes are managed internally. However, there are challenges in identifying measurements that accurately reflect impacts while minimizing data collection and maintenance efforts. The best options available for measuring operational impacts are outlined in Table 14 from least to most specific.

Table 14 Options for Development of Steelcase Process Profiles

Option	Accuracy
Use industry average profiles for process steps to be applied on a per weight basis to product assembly's total weight.	Low
Add Steelcase average plant-wide data on energy consumption (from multiple plants' total energy consumption) to generic process profiles based on square foot allocations to each process at Steelcase plants. Consumption of water, expendable processing materials and scrap represented by generic profile data in non-energy impact categories. Profiles applied on a per product basis.	Moderate
Build process profiles using Steelcase average plant-wide data on energy, water and expendable processing materials allocated by square footage. Include process related scrap rates. Profiles applied on a per product basis.	High
Use direct measurement of energy, water, expendable processing material and scrap flows on representative processes within Steelcase facilities and allocate overhead energy on a square foot basis to customized process profiles. Profiles applied on a per product basis.	Highest

The first option is sufficient for the earliest stages of product development when details on processes have not yet been determined and do not play a major role in the impacts of design decisions. For later stages of development, the second option in which energy allocations are made on a per square foot basis and combined with generic data to cover other impacts is the most feasible option before a significant investment is needed to calculate more accurate inputs and outputs. The remaining two options may warrant additional investigation as Steelcase continues to develop its environmental management efforts at the plant level.

Even the second option necessitates some investment in measuring process square footage and allocating general overhead energy to each process. It is also not an ideal calculation of impacts; the method also runs the risk of underestimating some process impacts and overestimating others. However, it has successfully been used in prior studies at Steelcase[74] and therefore should be sufficient until broader measurement efforts are put into place. This approach is described in Table 15.

---

[74] Dietz, Bernhard A. *Life Cycle Assessment of Office Furniture Products.* Center for Sustainable Systems, University of Michigan. April 5, 2005.

Table 15 Approach to Supplier Transportation Profiles

Recommended Approach to Steelcase Process Profiles	
Primary Inputs	Plant wide energy data and square foot measurements for major process categories (some involving multiple steps).
Calculations	Allocation of plant-wide energy consumption to process based on relevant square foot allocation.
Process Profile Content	Profile includes Steelcase energy allocation as well as generic impacts in other categories including water and waste inputs and outputs. Process profile acts as a single unit that is added to a product profile.

Substantial limitations remain with this approach. However, in meeting the needs of increasing accuracy while reducing investments of time and resources from operations managers as well as the time required of product developers to determine time or per weight bases for process calculations, this approach offers substantial benefits.

5.10 Steelcase Distribution

Distribution from Steelcase to its distributors and direct end customers presents degrees and types of impacts similar to those created by supplier transportation. Therefore, the needs for calculating distribution impacts parallel the supplier transportation approach, though distribution is ultimately calculated as a separate input feeding into the final product profile rather than as an input into supplier impacts. The options available for measuring distribution impacts are outlined in Table 16 from least to most specific.

Table 16 Options for Development of Distribution Profiles

Option	Accuracy
Use global average distribution distances based on weighted sales location data and average of truck transportation modes used in different regions[75].	Low
Use regional average distribution distances based on weighted sales data and truck transportation mode utilized in relevant region.	Moderate
Develop detailed profiles of sales locations and distances for each product and weight based on proportion of sales. Use truck transportation mode relevant to the global region (e.g. U.S. versus Europe).	High

While developing a detailed location profile offers more granular detail, this information is not always available during development and does not provide a significant benefit over using regional averages of typical sales locations. While a global profile can be

---

[75] Similar to analysis by Spitzley et al.

easily created from regional profiles, there is a challenge in that the same transportation modes result in different impacts in each global region due to varying standards.
The regional average profile provides a level of detail sufficient for representing likely distribution impacts. It is also relatively simple to construct because historical sales data including distributor and direct customer locations is already available, and because Steelcase tends to use the same truck-based mode of transportation for all distribution. This approach is described in Table 17.

Table 17 Approach to Distribution Profiles

Recommended Approach to Distribution Profiles	
Primary Inputs	Generic truck distribution mode for each region and historical data on each region's distributor and customer locations.
Calculations	Weighting of distances based on proportion of distributors and customers at that distance from Steelcase plants.
Average Distribution Profile Content	Each regional profile includes generic truck transportation at weighted distance to distributors/customers to reflect average regional impacts.

This approach allows product developers to account for general distribution contributions to total product impacts without requiring significant input on distributor and customer locations.

5.11 Use and End of Life Scenarios

The stages of customer use and product end of life are largely outside the control and monitoring of Steelcase and the use phase in particular is of less concern in furniture production than in other products that use significant amounts of energy over their life spans. However, the use phase can play a role in design decisions when lighting is included in a furniture solution. In these cases, developers can influence the extent and type of lighting solution and therefore influence use phase impacts. The end of life stage is almost entirely out of Steelcase's control as the company does not currently reclaim products. However, the end of life scenario does play a role in reporting on product recyclability and can be influenced in a general sense by designing products for disassembly.

Use scenarios are built into WELE by allowing developers to select quantities and types of lighting included in the product profile as well as an estimated lifespan for the product's use. Using these three inputs in WELE, SimaPro can automatically calculate the impacts of lighting energy consumption over the product's useful life based on a regional (e.g. U.S. versus Europe) electricity profile. These impacts are linked to the product's life cycle profile to reflect contributions towards total life cycle impacts.

Three end of life scenarios are available through WELE: (1) a profile of low recycling and high solid waste disposal for different types of materials, (2) a profile representing average U.S. recycling and disposal rates for the same materials, and (3) a high recycling rate profile that represents the optimal recycling scenarios for these materials[76]. The third profile can be used when developers have set specific disassembly goals that encourage a greater degree of material recycling at the end of life. Because this is a simplified quantification of a largely qualitative product design feature, use of the third profile will require justification from the product developers and verification by environmental experts at the appropriate stage-gate review. Each of the three profiles assumes individual recycling rates for each material category. The reporting processes incorporated into WELE take these recycling profiles into consideration when calculating product life cycle impacts based on the product's input quantity of each material category.

5.12 Data Integration and Management

A final consideration is the integration of WELE tool with broader IT systems at Steelcase. Concurrently with the tool's development, a major IT project was initiated at the company and the integration of environmental metrics into IT systems was included as an element in this project. This presents significant opportunities to match environmental data tracking with product development needs through WELE.

Early discussions with IT and supply chain representatives at Steelcase[77] indicated the potential for specific environmental performance metrics to be associated with suppliers and processes that are tracked for operational purposes through SAP and other databases. Using these external sources for data storage and linking data points to profile templates within SimaPro would be significantly simpler for data quality management and updates to profiles than maintaining the data in SimaPro separately from other systems. While implementation has yet to be realized, this approach would be feasible through a COM interface linking the external databases with SimaPro.

Additional work needs to be conducted to determine responsibilities for data collection and management and to determine the extent of data collection. To meet the needs of Steelcase-specific profiles for materials, processes, and distribution, representatives of supply chain management, operations, and sales need to be involved in some aspects of collection. The IT and environmental departments must also be involved in integration

---

[76] For each material, the "low recycling" scenario assumes a rate 80% lower than the current average rate and the "high recycling" scenario assumes a rate 80% higher than the current average rate. For example, in the "low recycling" profile, ferro scrap is recycled at a rate of 5.6% (meaning 94.4% is disposed of rather than reused). In the "average recycling" profile, ferro scrap is recycled at a rate of 28.0% and in the "high recycling" scenario, ferro scrap is recycled at a rate of 50.4%.

[77] Discussions with MaryEllen Mika (supply chain) and Cathy Cummins (IT).

and upkeep of data as it evolves over time, which is currently limited to a manual process but could be automated in relation to other IT systems. In addition, verification of data quality will be necessary. This verification can be conducted in-house at Steelcase or through an external environmental auditing process[78].

Particularly concerning data collection from suppliers, response rates will be a challenge regardless of incentives and minimization of efforts. The Steelcase supply chain largely consists of 25-50 suppliers that provide the vast majority of materials and components[79]. By targeting this group rather than attempting to gain compliance across all potential suppliers, the likelihood of providing relevant incentives and gaining increased participation can increase dramatically.

The process of collecting and integrating data into usable states will take substantial time and will likely reveal further methods for accurately reflecting Steelcase-specific impacts based on various proxy sources. The suggested approaches explored as part of this research serve as a starting point for this broader exploration and testing of data development, and will need to be weighed by the environmental, IT and other teams that would be involved in its collection.

---

[78] Such external auditing is pursued by many companies to verify general supply chain environmental and social performance as required by each company. An interesting discussion of one such program at HP is available at www.hp.com/hpinfo/globalcitizenship/gcreport/supplychain/conformity/verification.html. Last accessed April 2008.

[79] Discussion with Steelcase supply chain representative.

6.0 Case Studies

Two sets of case studies have been conducted to test the accuracy of results when products are evaluated in WELE throughout the product development cycle. First, the impact of using generic versus Steelcase-specific data in early stages of development was tested using previously completed Life Cycle Analyses (LCAs) of three Steelcase products. These LCAs used a number of material, process, and transportation input profiles based on internal Steelcase data. The case studies conducted as part of this research test the difference in impacts between these input profiles and their generic data counterparts as well as the difference in calculations of full product impacts when generic data is used in lieu of internal Steelcase data.

This first set of studies indicates that impact estimates for individual materials, processes, and modes of transportation vary significantly between generic and specific profiles. However, the contributions of these differences to estimates of full product impacts are less extreme, particularly in the case of process and transportation profiles that play less significant roles in total product impacts. Differences in material impact calculations played the most significant role in altering full product impact assessments.

The second set of studies used the same three products to test a particularly critical aspect of the tool – the degree to which early stage models of products can reflect final environmental impacts. The WELE approach of building product profiles over time relies on a fundamental assumption that some degree of accuracy is feasible when estimating the potential environmental impacts of a product before it is fully designed. While an early stage model cannot reflect all final impacts, it should reflect impacts within a certain range of the final results.

These studies indicate that a relatively high degree of accuracy is possible even in the earlier stages of design. As the product moves through development, increases in accuracy are consistent across the three products. Therefore, an assumption that environmental impact estimates are within a certain degree of accuracy at each stage of development appears to be feasible, and this approach would be in line with Steelcase's existing assumptions about cost estimate accuracy at each stage of development.

6.1 Approach and Methodology

The three products used in the case studies are referred to as Airtouch Table, Garland Office System, and Slim Chair for the purpose of this report. The products are shown in Figure 24. These products represent a range of functional uses and also represent a range of dominant materials used in design: aluminum for the Airtouch Table, wood and laminates for the Garland System, and plastics, steel, and leather for the Slim Chair.

Figure 24 Airtouch Table, Garland Office System and Slim Chair (L to R)

The three products were evaluated after their development by researchers at the Center for Sustainable Systems (CSS) using standard LCA assessment methodologies[80]. Each evaluation used Steelcase-specific data in various calculations when available. In the first set of case studies for the current research, Steelcase-specific data is compared to generic data. In the second set, the accuracy of impact assessment at each stage of product development is evaluated by making assumptions about the product elements known at each stage[81]. The assessments at each stage are then compared to the final product assembly to determine the degree to which impacts are represented at concept, design, and engineering.

While WELE would ideally be tested on products as they proceed through development in real time, the release of multiple tool iterations and Steelcase's development timeframes for product development made it infeasible to include such tests in this phase of research. However, a variety of opportunities to test products during development will emerge in the near future as WELE begins to be used.

Basing analysis on previously completed evaluations presents some benefits. The three products were evaluated using the same methodologies by the same set of researchers, so concerns about the influence of different evaluation approaches are mitigated. The evaluations were developed in SimaPro which minimizes the need to translate data into a format compatible with WELE. Finally, the rigor of the evaluations results in product profiles that truly represent impacts, allowing for relevant comparison between profiles of products during development and the final impacts of these products.

---

[80] Spitzley, David V. et al. *Life Cycle Assessment of Office Furniture Products: Final Report on the Study of Three Steelcase Office Furniture Products.* Center for Sustainable Systems, University of Michigan. Report No. CSS06-11. July 7, 2006.

[81] Based on discussions with Steelcase product developers.

In both sets of case studies, a simplified set of six LCA-relevant metrics were used to compare results, identical to those used in the earlier CSS product evaluations. These metrics and their abbreviations are listed in Table 18.

Table 18 LCA Metrics Used in Case Studies

Metric	Abbreviation
Energy resource consumption	ERC
Global warming potential	GWP
Acidification potential	AP
Criteria pollutants	CP
Solid waste	SW
Total material consumption	TMC

These six metrics are useful in reflecting some of the most critical areas of life cycle impacts from products. As in the previous evaluations, TRACI was used as the assessment framework due to its relative robustness in reporting on these metrics, inclusion in SimaPro, and application to U.S. assessments of environmental performance.

6.2 Generic vs. Steelcase Data Comparisons

The first set of case studies looks at the criticality of Steelcase-specific data in determining total product impacts. This criticality is based on the degree of variation between generic and Steelcase-specific data across the six impact categories. The degree of criticality found in these analyses is important in two respects. A high level of variation from generic data, and thus large differences in assessment of total product impacts, indicates the need for development of Steelcase-specific data sets as discussed in Section 5.0. At the same time, a certain degree of similarity between generic and Steelcase-specific data is desired if generic data is to be used in early stages of product development.

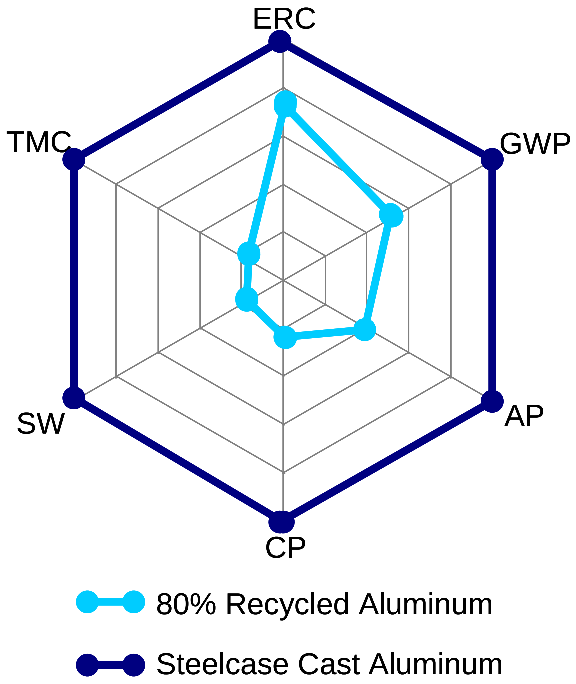
6.2.1 Materials

Airtouch Table, Garland Office System, and Slim Chair differ in their primary material makeup. Airtouch uses significant quantities of aluminum, Garland uses wood and laminates, and Slim Chair uses a combination of plastics and steels. This range of materials is representative of major material categories used by Steelcase across products.

Each material was evaluated to identify a generic data proxy similar to its functionality and production process. A list of the relevant Steelcase-specific materials and their generic proxies organized by relevant product components is included in Appendix D.

In a one to one comparison of Steelcase-specific materials with their generic counterparts independent of their inclusion in a product profile, significant differences in impacts were observable across material categories.

An example is the difference between a Steelcase cast aluminum used in the original analysis of the Airtouch Table and a generic 80% recycled aluminum, which has a recycled content similar to the cast aluminum. While the cast aluminum represents 100% of final impacts, the 80% recycled proxy represents a range of 19% - 73% of these impacts across the categories. The results of this comparison are in Figure 25.



	80% Recycled Aluminum	Steelcase Cast Aluminum
ERC	73%	100%
GWP	55%	100%
AP	40%	100%
CP	23%	100%
SW	19%	100%
TMC	19%	100%

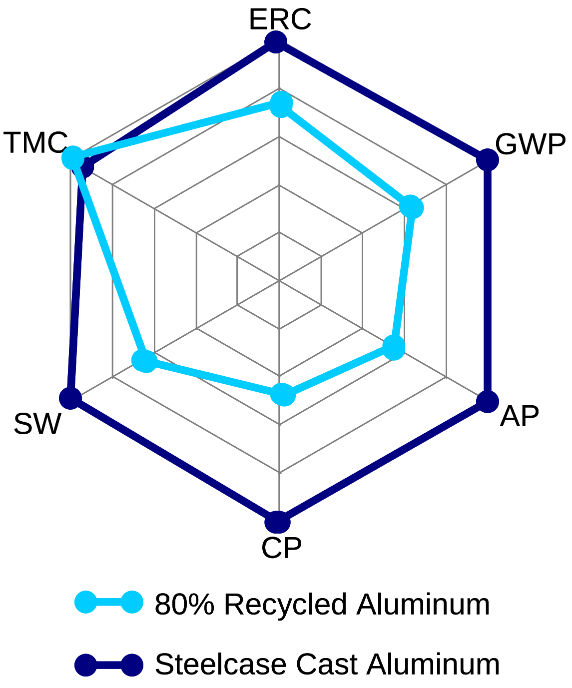
Figure 25 Steelcase vs. Generic Aluminum Individual Material Comparison

The differences in this case stem from a number of basic calculation differences in the generic and Steelcase data. The lower global warming potential (GWP), acidification potential (AP), and criteria pollutants (CP) from generic 80% recycled aluminum are due to different calculations of emissions. The generic data is attributed similar carbon dioxide emissions but has much lower estimations of carbon monoxide, sulfur dioxides, nitrogen oxides, and particulates than the Steelcase data. Solid waste and total material consumption are driven by different calculations of waste quantities. Even with similar recycling rates, the solid waste associated with the Steelcase material is estimated at more than five times that of the generic material; this is likely due to different regional data on waste management for the material. Full data on the percentage of impacts represented by generic data across material categories for the three products is included in Appendix E.

This degree of difference is due in part to differences in analysis of the materials themselves (i.e. different methods for collecting and evaluating data to create the material profile in SimaPro) and different degrees of quality data feeding into the profiles of each material. However, these data discrepancies do not appear to be significant in most cases and differences between the materials' impacts seem to be primary drivers of variation. One such indication is that total material consumption, which includes not only the final material weight but the weight of all input and output materials, is similar in many cases. This indicates that the same general input/output factors are largely being taken into account. In cases where TMC data is not the same (as in Figure 25), treatment of solid waste seems to be a critical area of difference.

While these are significant differences between individual materials, their impacts within a full assembly or product profile become diluted because of the wide variety of inputs into the profile. Profiles of assemblies and full products with generic data show somewhat more accurate measures of impacts, at an average range of 60-80% of the impacts represented by Steelcase-specific materials. Profiles of the three full products with generic material data show similar ranges of variation.

The impact of generic aluminum data in the full Airtouch product is an example. By contrast to the individual material comparison in Figure 25 where impacts were significantly different, the effect of replacing the Steelcase aluminum with the generic aluminum is diluted when other inputs to the product are also considered. The generic data in the full profile represents a range of 69% -86% of final impacts across most impact categories. The results of this comparison are shown in Figure 26.



	80% Recycled Alum. in Airtouch	**Steelcase Cast Alum. in Airtouch**
ERC	77%	100%
GWP	82%	100%
AP	73%	100%
CP	69%	100%
SW	86%	100%
TMC	100%	94%

Figure 26 Steelcase vs. Generic Aluminum Comparison in Full Product

This indicates that while generic materials measurements differ significantly in their impact representation, their impacts within assemblies and full products come closer to approximating the impacts represented by Steelcase specific materials[82]. At the same time, this makes the case that there is still some value in incorporating Steelcase specific materials to close the gap on total impacts from 70-90% to 100% of the actual impacts.

Full data on the percentage of impacts represented by generic data in component and full product profiles is included in Appendix F.

Ultimately, these results recommend a middle ground in which generic data can be used in early stage development of product profiles with the understanding that accuracy is somewhat limited, and in which specific Steelcase data plays an essential role in the accurate measurement of impacts in later stages of development.

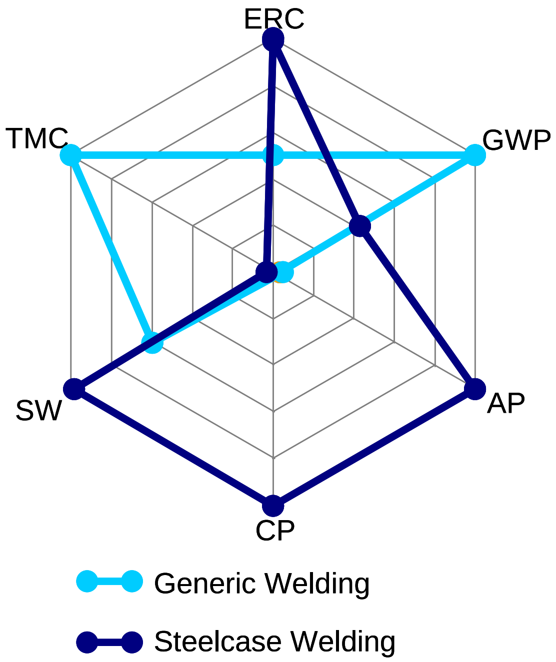
6.2.2 Processes

Processes were evaluated in a manner similar to materials, though fewer data points were available in this category. In quite a few cases, profiles for electricity use were the closest available proxies for energy-intensive processes. To make comparisons in these cases, an amount of electricity equal to that feeding into the specific process profiles was applied as the comparison data. All processes and their generic proxies are listed in Appendix G. Overall, comparisons on both an individual process and full product basis were more favorable than the material comparisons. On a one to one basis, process impacts ranged widely with some generic data proxies representing up to 99% of Steelcase-specific impacts but others representing as little as 7% of these impacts.

Welding was one of the more extreme process comparisons in Airtouch, independent of the product profile. Here, impacts vary drastically while other proxies are more representative of final impacts. The results of this comparison are shown in Figure 27.

---

[82] Similar to Turkstra's rule, as discussed in Naess, A and Røyset, Johannes. *Extensions of Turkstra's Rule.* Structural Safety. Volume 22. Issue 2. June 2000. Pgs 129-143.



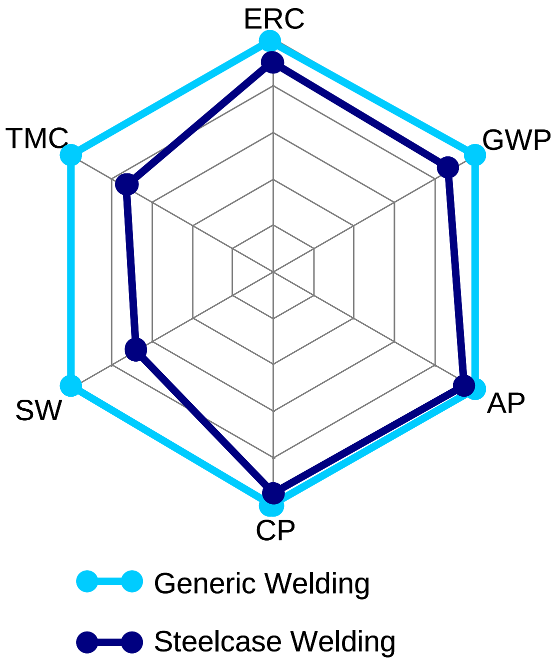
	Generic Welding	Steelcase Welding
ERC	54%	100%
GWP	100%	46%
AP	5%	100%
CP	1%	100%
SW	60%	100%
TMC	100%	4%

Figure 27 Steelcase vs. Generic Welding Individual Material Comparison

In this case, the differences between generic and Steelcase data are due to the inclusion of certain impact data in each profile. The generic data uses an electricity input that is particularly greenhouse gas intensive and is less intensive than other electricity input options in terms of acidification potential and criteria pollutants beyond those that overlap with greenhouse gases. The generic process also uses less energy than the Steelcase one; as a result, the generic data has a much higher global warming potential profile but much lower energy resources consumption, acidification potential, and criteria pollutant profiles than the Steelcase data. As with the aluminum profile, the difference in solid waste is due to different estimates of total waste material. However, the generic data also assumes a higher level of material inputs even though it has less waste. Therefore, the solid waste and total material consumption differences are divergent in this comparison.

Full data on the percentage of impacts represented by generic data across processes used in the three products is included in Appendix H.

When generic process proxies are applied to assemblies and the full product, the result is similar to that found in the material analyses, with data accuracy limitations in individual cases mitigated by the variety of other inputs into the product. Even when highly variable generic data is used, the contributions of generic processes to total impacts are comparatively low, as seen in Figure 28, in contrast with Figure 27. This is due to the fact that processes play a relatively small role in total product impacts in comparison with materials.



	Generic Weld in Airtouch	Steelcase Weld in Airtouch
ERC	100%	95%
GWP	100%	93%
AP	100%	98%
CP	100%	98%
SW	100%	72%
TMC	100%	76%

Figure 28 Steelcase vs. Generic Welding Comparison in Full Product

The reasons for mitigated impacts in Figure 28 are similar to those in the comparison of cast aluminum with generic data in Figure 25. Full data on the percentage of impacts represented by generic process data in component and full product profiles is included in Appendix I.

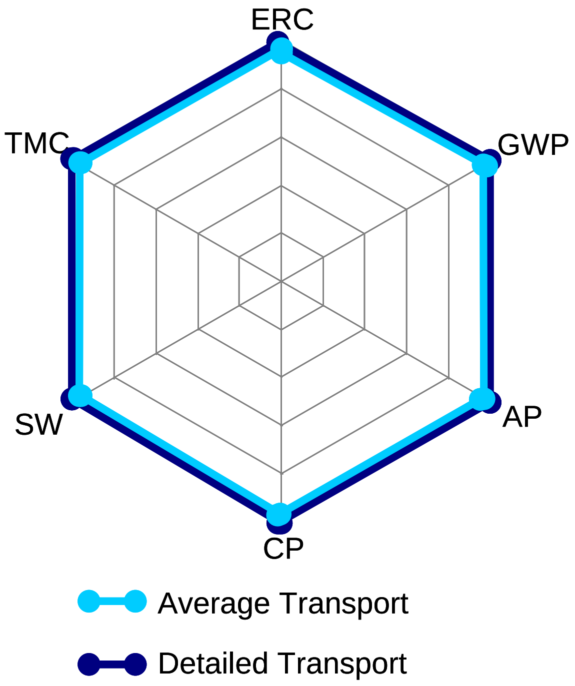
These results are promising in that they indicate the potential for relatively accurate results in early stages of development when specific processes are not yet identified because the processes play a lesser role in total impacts than materials. However, in accurately representing impacts particularly in Stage 3 (Process) of development, some Steelcase-specific data will be essential due to variations between Steelcase and generic data inputs.

6.2.3 Transportation

The final input area analyzed across the three products was transportation profiles. Supplier and distribution transportation both factor into total product impacts, though each is handled differently in WELE itself. While Steelcase product developers have far less choice in altering transportation inputs than in selecting alternative materials and processes, understanding the influence of Steelcase specific transportation profiles on estimates of total environmental impacts is essential.

This analysis focused on distribution impacts because supplier transportation was built into the original profiles to a limited degree, specifically focusing on inter-plant transportation within Steelcase and therefore creating difficulties in conducting a broader analysis of transportation throughout the supply chain. For distribution, each completed product analysis included detailed information on shipping distances to selected U.S. regions weighted according to the proportion of customers in each region. Average and maximum distance profiles were created for each product to simulate standard distribution profiles that might be used before more specific distribution data is known. These profiles are included in Appendix J. Because distribution profiles apply to the whole product, comparisons between Steelcase-specific and generic data were only conducted at this level.

The impact of average transportation profiles for distribution in Airtouch is representative of the minimal impact of generic versus Steelcase-specific data in this category. The results of this comparison are shown in Figure 29.



	Average in Airtouch	Specific in Airtouch
ERC	99%	100%
GWP	99%	100%
AP	99%	100%
CP	99%	100%
SW	100%	100%
TMC	100%	100%

Figure 29 Specific vs. Average Distribution Comparison in Full Product

Full data on the percentage of impacts represented by average and maximum distribution profiles in the complete product profiles is included in Appendix K.

Comparing the average distances led to somewhat unexceptional results, with almost all total impacts represented despite the use of less specific transportation data. By contrast, comparing the maximum distance with the Steelcase-specific regional data creates a much higher level of variation. However, this approach does not provide significant benefits over average distances and therefore does not need to be used in WELE.

This indicates that distribution transportation as a whole plays a fairly minor role in the discrepancies between Steelcase-specific and generic data in calculating total product impacts. One area that may change this finding slightly is the inclusion of average versus specific supplier transportation data. However, because averages are fairly accurate on the distribution end, supplier transport may also be well represented by averages without significantly reducing model accuracy.

6.2.4 Future Needs for Analysis

The above analyses indicate that it is feasible to use generic data when more specific data is unavailable but that Steelcase specific data plays an essential role in representing total environmental impacts, particularly in the material and process categories. At the same time, this data is based on three examples and there is the potential for additional evaluation as the tool is used and new products move through development. It will be particularly valuable to track early stage profiles and compare them directly to final product profiles to determine the precise impacts of using generic data early on.

6.3 Development Stage Comparisons

The second set of case studies looked at the degree to which environmental impacts can be represented in each stage of product development. This incorporates aspects of the previous comparison between generic and specific data as well as input on the product design process and what is expected to be known in each stage about product structures as well as materials, processes, and transportation. Comparisons were based on the assumptions about known inputs at each stage of development, as described in Table 19.

Table 19 Assumed Known Product Elements by Development Stage

Stage	Known Product Elements
0 (Concept)	Primary materials in the product, represented by generic data
1 (Design)	Major components and materials in the product, represented by a combination of generic and specific data
2 (Engineering)	All components and materials, represented by specific data
3 (Process)	Addition of processes and packaging to the product profile
4 (Reporting)	Full product inputs and outputs represented by the previously conducted LCAs for each product

The detailed profiles used to represent known components and inputs at each stage of development are included for all three products in Appendix L. These profiles were entered into SimaPro and tested against the full LCA profiles from previous research. In addition, a target for these stage-based comparisons was derived from Steelcase's assumptions about cost estimate accuracy throughout product development. These estimates are described in Table 20 and serve as the basis for targets in this analysis.

Table 20 Cost Estimate Targets Used as Basis for Analysis

Stage	Cost Estimate Target[83]
0 (Concept)	No cost estimates
1 (Design)	Within +/- 30% of final costs
2 (Engineering)	Within +/- 15% of final costs
3 (Process)	Within +/- 10% of final costs
4 (Reporting)	100% of costs represented

Ideally, representation of environmental impacts will follow a similar pattern of increasing accuracy and will be within a similar range so as to fit with current development expectations.

The results for each product were derived from assumptions about known components and inputs and the detailed modeling profiles. Results for Airtouch are shown in Figure 30 and described by percentage in Tables 21 and 22. Results for Garland are shown in Figure 31 and described by percentage in Tables 23 and 24. Results for Slim Chair are shown in Figure 32 and described by percentage in Tables 25 and 26.

6.3.1 Airtouch Results

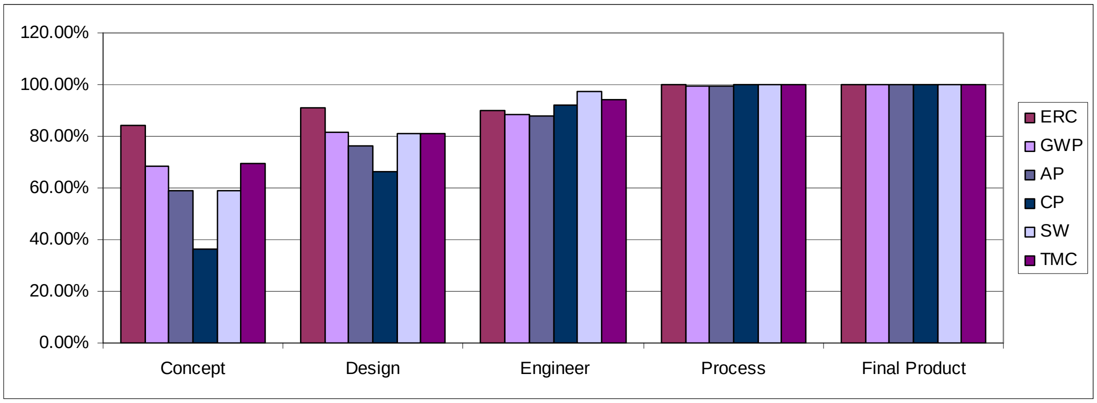


Figure 30 Airtouch % Impacts Represented by Development Phase

---

[83] From discussion with product development representatives.

Table 21 Airtouch % Category-Based Impacts Represented by Development Phase

% Impacts Represented	ERC	GWP	AP	CP	SW	TMC
0 (Concept)	84%	69%	59%	37%	59%	70%
1 (Design)	91%	82%	76%	66%	81%	81%
2 (Engineering)	90%	89%	88%	92%	97%	94%
3 (Process)	99%	99%	99%	99%	100.00%	99.97%
4 (Reporting)	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Table 22 Airtouch % Total Impacts Represented by Development Phase

% Total Impacts Represented	Minimum	Maximum	Average
Concept	37%	84%	63%
Design	66%	91%	80%
Engineer	88%	97%	92%
Process	99%	100.00%	99%
Final Product	100.00%	100.00%	100.00%

6.3.2 Garland Results

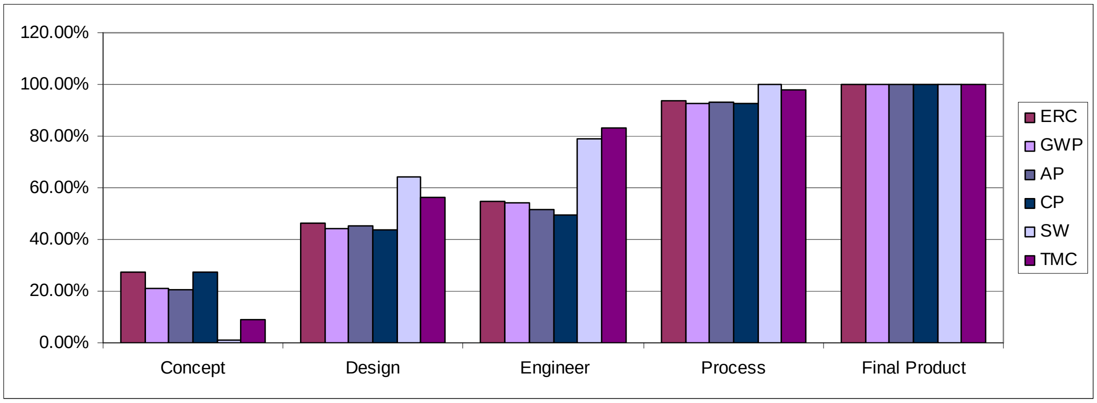


Figure 31 Garland % Impacts Represented by Development Phase

Table 23 Garland % Category-Based Impacts Represented by Development Phase

% Impacts Represented	ERC	GWP	AP	CP	SW	TMC
0 (Concept)	27%	21%	21%	27%	1%	9%
1 (Design)	46%	44%	45%	44%	64%	56%
2 (Engineering)	55%	54%	51%	50%	79%	83%
3 (Process)	94%	93%	93%	93%	99%	98%
4 (Reporting)	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Table 24 Garland % Total Impacts Represented by Development Phase

% Total Impacts Represented	Minimum	Maximum	Average
Concept	1.09%	27.35%	17.71%
Design	43.55%	64.41%	50.05%
Engineer	49.47%	82.90%	61.98%
Process	92.60%	99.87%	94.95%
Final Product	100.00%	100.00%	100.00%

6.3.3 Slim Chair Results

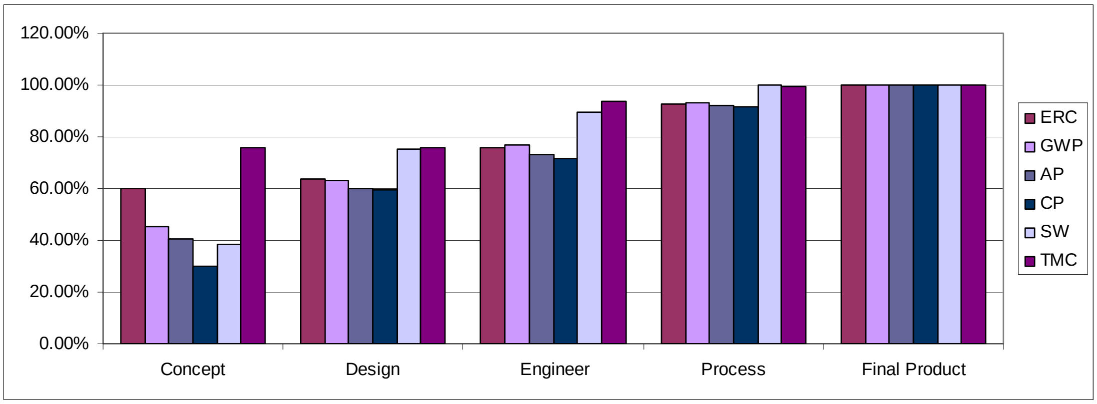


Figure 32 Slim Chair % Impacts Represented by Development Phase

Table 25 Slim Chair % Category-Based Impacts Represented by Development Phase

% Impacts Represented	ERC	GWP	AP	CP	SW	TMC
0 (Concept)	60%	45%	41%	30%	38%	76%
1 (Design)	63%	63%	60%	60%	75%	76%
2 (Engineering)	76%	77%	73%	72%	89%	94%
3 (Process)	92%	93%	92%	92%	99%	99%
4 (Reporting)	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Table 26 Slim Chair % Total Impacts Represented by Development Phase

% Total Impacts Represented	Minimum	Maximum	Average
Concept	30%	76%	48%
Design	60%	76%	66%
Engineer	72%	94%	80%
Process	92%	99%	95%
Final Product	100.00%	100.00%	100.00%

There is some variation across the products in how well they match the financial estimate expectations, though the Airtouch exceeds these expectations and the Slim Chair comes very close to meeting them. At minimum, all three products show the pattern of increasing accuracy as they get closer to the final product.

In evaluating why there is some variation in accuracy, particularly in the Garland's early stage inaccuracy across multiple impacts, it appears that this is due in part to the materials used and the number of processes represented. The Garland system relies heavily on wood products, which showed the greatest gaps in representation of environmental impacts between generic and Steelcase specific materials among the material comparisons. In addition, the Garland system as modeled in SimaPro used the greatest amount and widest ranging processes for production as well as greater amounts of packaging, both of which were not taken into consideration until the Process phase. Therefore, the gaps in accuracy between concept, design and engineering when specific materials are increasingly included and the leap from engineering to process in which production and packaging are added become more significant for Garland than for the Airtouch and Slim Chair examples.

The concern that Garland does not meet the expectations for accuracy at different stages could partially be solved by developing more detailed material data for wood products. Modifying the concept phase design to assume more accurate wood product data shows the degree of influence that wood data has on calculations of environmental impacts at this stage. The comparison between the modified and earlier concept stage accuracies is shown in Figure 33 and described by percentage of total impacts in Tables 27 and 28.

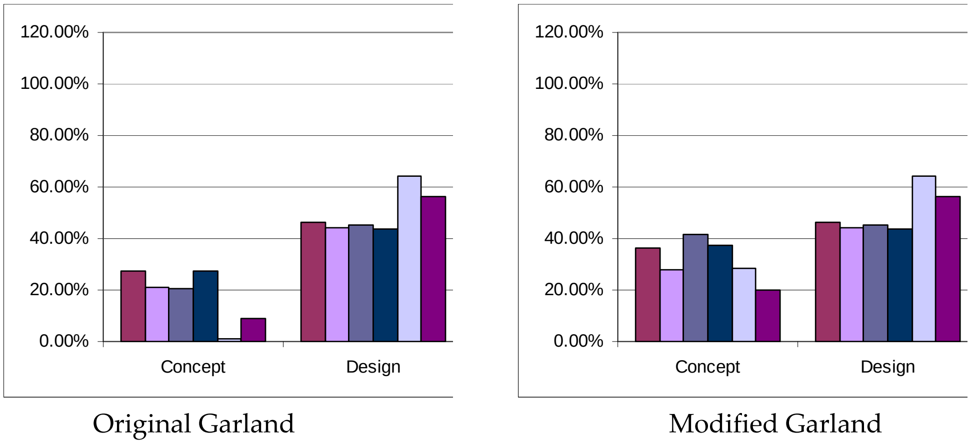


Figure 33 Modified Concept Phase Impacts on Garland % Impacts Represented

Table 27 Modified Concept Phase Impacts on Garland % Category-Based Impacts

% Impacts Represented	ERC	GWP	AP	CP	SW	TMC
0 (Concept)	27%	21%	21%	27%	1%	9%
0 (Modified Concept)	37%	28%	42%	38%	29%	20%
1 (Design)	46%	44%	45%	44%	64%	56%
2 (Engineering)	55%	54%	51%	49%	79%	83%
3 (Process)	94%	93%	93%	93%	99%	98%
4 (Reporting)	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Table 28 Modified Concept Phase Impacts on Garland % Total Impacts

% Total Impacts Represented	Minimum	Maximum	Average
Concept	1%	27%	18%
Modified Concept	20%	42%	32%
Design	44%	64%	50%
Engineer	49%	83%	62%
Process	93%	99%	95%
Final Product	100.00%	100.00%	100.00%

Based on the modification of wood products, the concept phase for Garland comes much closer to those of the other two products. The remaining discrepancies between Concept and Design for Garland are due to the inclusion of metal inputs in the design phase that would not be known in the concept phase. Therefore, there is still a discrepancy but improved data on wood impacts available to concept phase designers would help identify their contribution to the final product's environmental impacts with greater accuracy.

The issue of wood data accuracy could be resolved by including more appropriate proxies such as those based on Steelcase averages for wood products rather than incomplete industry data. It is also potentially mitigated by earlier identification of major processes involved in the product, which is likely because this simulation was based on the last possible identification of processes as an extreme case whereas in reality, some processes are identified in Phase 2 (Engineering).

Finally, when viewed on average, the degrees of accuracy are promising. Across all three products, the average accuracy is similar to the cost estimate targets for accuracy at each stage. These are compared in Table 29.

Table 29 Comparison of Impact Assessment Accuracy with Cost Targets

Stage	Cost Estimate Target	Average Tested Product Accuracy
0 (Concept)	No cost estimates	Within 57% of final impacts
0 (Concept Modified)	No cost estimates	Within 44% of final impacts
1 (Design)	Within +/- 30% of final costs	Within 35% of final impacts
2 (Engineering)	Within +/- 15% of final costs	Within 22% of final impacts
3 (Process)	Within +/- 10% of final costs	Within 4% of final impacts
4 (Reporting)	100% of costs represented	100% of impacts represented

While not perfectly aligned, accuracy levels are close to the cost estimate accuracy targets already used in product development. With some improvements in data availability for materials and processes like those used in the Garland Office System, the average can be brought well within the needed range.

6.3.4 Future Needs for Analysis

The analyses of products moving through each stage of design indicate that, while product information is not perfect in early stages, the level of accuracy is comparable to expectations for early cost estimate accuracy. Matching these expectations is critical in assuring developers of the tool's value at these early stages and giving them a guide for expectations throughout development.

The comparisons to cost estimates are not exactly perfect; particularly in the Design and Engineering phases, additional boosts in data accuracy would be desirable to bring accuracy from within 34% to 30% in the Design phase and 22% to 15% in the Engineering phase. As the Garland example demonstrated, much of this could be achieved by building in data for materials that are not currently represented in WELE and by building in Steelcase-specific data over time that can be used for average material and process profiles in early development.

As with the study of specific material, process and transportation profiles, additional data from completed products will become available as WELE is used by product developers. Tracking and maintaining data points from these completed profiles can be valuable in building up more specific data for use in early development.

Finally, further case studies can be developed by tracking new products as they move through development and are evaluated in the tool. There may be discrepancies between the current analysis of completed products using assumptions about degrees of information at each stage of development and the actual knowledge about product inputs as they move through the stage gate process. Either way, additional data leading to more robust accuracy estimates at each stage of development would be valuable.

7.0 Conclusions and Recommendations

The purpose of this research was to evaluate the potential for a data-driven approach to life cycle analysis of products during their development. The analytical structure of the tool's interface, reporting methods, and data inputs all play critical roles in the success of such a tool. Conclusions about the feasibility of this tool in practice were drawn from its development as well as from the case studies conducted to test data inputs and accuracy at various stages of product development and recommendations are made for further development of this research.

7.1 Conclusions

7.1.1 Tool Development

A data-driven, life cycle analysis based approach has significant advantages in its potential for accurate representation of total product impacts and its access to a wide variety of data that would be difficult to collect independently. Development of the beta version of WELE indicated strong potential for a data-driven environmental analysis tool in early stage product development. Most critical aspects of life cycle analysis could be incorporated and a basic functional interface was successfully developed for use by non-experts. The tool's viability is particularly evident when is compared with the use of separate metrics or assessments of individual materials to estimate environmental impacts during product development.

Usability concerns can be addressed through short and long term improvements such as linking other interfaces to the LCA software and improving interface development within the platform itself. Usability concerns surrounding the tool were significant. A critical lesson learned during this process was the limitations of existing LCA software platforms in meeting non-expert desires for ease of use. Steelcase can address some of these concerns in the short term through the exploration of linkages between the LCA software and existing IT systems. In the long term, developers of LCA software can improve the functionality of their tools to expand beyond expert users and meet the needs of non-experts.

A data-driven, iterative, and output oriented approach to environmental analysis is most valuable to an organization where environmental experts have limited capacity to work directly with product developers. The need for environmental analysis was found to vary widely across organizational structures, and these differences should be considered when designing tools for product developers. The ratio between available environmental experts and product developers alters the degree to which dissemination of environmental decision making is necessary. The assumptions about the purpose of environmental analysis that are adopted by different organizations and regional groups also contribute to varying expectations for tool functionality.

7.1.2 Reporting

At present, almost all existing environmental metrics used by Steelcase product developers can be reflected in WELE using the standard SimaPro reporting structure. Three of the four metrics and frameworks were integrated with minimal or no concerns about usability. A notable exception was the measurement of non-numerical metrics that rate inputs like materials based on binary or qualitatively coded metrics.

There remain many possible improvements to the visual and table-based formats available through the SimaPro platform. In addition to allowing the incorporation of qualitative metrics, greater flexibility in reporting outputs, storage, and translation to other programs would increase the tool's usability. Like other usability factors, this can be viewed as a positive opportunity to reach a broader audience with the platform.

7.1.3 Data Development

Data accuracy is best achieved by measuring the impacts of a company's own operations and supply chain. This data should be provided to developers as long as it relies on investment proportionate to the criticality of the data and can be collected with an acceptable degree of accuracy. Internal data was found to play a critical role in accurately reporting impacts as these impacts can vary greatly across companies and among suppliers. Because primary data on the impacts of materials, processes, transportation, use and end of life play are significant, the accuracy of WELE relies on valid input data in these categories. At the same time, efforts to determine data collection methods that provide accuracy while relying on reasonable investments in data calculation illustrated the challenge of balancing these needs.

Data collection should rely on existing systems and appropriate incentives to provide robust data inputs that can be managed over time. The exploration of collecting and integrating Steelcase-specific data into SimaPro revealed opportunities to partner with suppliers and measure internal operating data with relatively low investment. While there is a tradeoff between data accuracy and a realistic need to minimize time investments, a middle ground approach that effectively utilizes incentives and existing systems has the potential for long term, low impact data collection and reflection of this data in evaluation of product impacts.

Testing of different approaches to data collection needs to be conducted within the company. A significant amount of work remains to test recommended data collection methods and explore additional approaches. The approaches designed to minimize time and resource requirements still necessitate some degree of action and may rely heavily on incentives for participants. Therefore, implementation work is needed to verify the true feasibility of data collection and management over time.

7.1.4 Case Studies

Generic data is appropriate for the earliest stages of product development while company-specific data plays a valuable role in later stages. Case study evaluations of three Steelcase products validated the approach of using a combination of generic and Steelcase-specific data at different points of product development. Working with known inputs at different stages of development, generic data appears to be an appropriate input in early stages as long as developers are aware of its limitations on accuracy. In later stages, Steelcase-specific data becomes critical for meeting increasing expectations about accuracy as the product becomes more refined.

Assumptions about accuracy can be made for each stage of product development, and these assumptions are generally in line with targets for cost estimates at each stage. The case studies specifically evaluating progression through different stages of development illustrated that achieving degrees of accuracy similar to the targets set for cost estimates is feasible. The product that was significantly outside assumed accuracy targets for each stage included less accurate generic data than the others. This further supports the need to provide accurate data profiles for use throughout development.

7.2 Recommendations

Based on the beta version of WELE and results in supplementary data and reporting areas, it is recommended that Steelcase continue with implementation of the tool. While concerns exist in each area, the progress made over the course of this research indicates that the tool has high potential in the long term.

To bring the tool into immediate use, training of product developers in the use of the tool is needed. This will ensure a base of knowledge about the process of evaluating products as a whole, the expectations for accuracy at each stage of development, and the general functionality of the tool. Such training can also result in further usability improvements, as seen in the initial training and testing sessions conducted during the tool's development.

In the long term, updates to the SimaPro software will improve user interaction with the tool. In the short term, exploration of alternate interfaces should be continued to determine whether more streamlined and intuitive user interfaces are feasible. Some usability issues raised during the development of WELE remain a concern and have not yet been addressed through changes to SimaPro. The most critical are to build in greater flexibility in wizards coding in order to allow product profiles to be saved in various locations, automatic updating of product, material, and process lists, and performance of multiple selections and/or actions on a single wizard screen.

As with user interaction issues, fundamental changes to the SimaPro platform are needed to increase the flexibility of reporting frameworks and formats. Reporting usability has been resolved for most existing Steelcase metrics and assessment frameworks. However, additional exploration of alternate ways to represent Cradle to Cradle ratings would be of value in the short term. The most critical reporting recommendations are to integrate non-cumulative measurements (e.g. binary) that would allow the use of a wider variety of assessment frameworks and to provide a greater variety of visual displays for reporting information.

Steelcase will need to establish concrete targets for each relevant impact category and priorities among these categories. While metrics have been shared with product developers, targets for performance are not always clear. Establishing fixed goals for environmental performance will assist developers in the interpretation of results and prioritization of design modifications based on environmental impacts.

Integration with company-wide IT initiatives and development of incentives for suppliers are critical next steps in developing company-specific data inputs. The recommendations in Section 5.0 serve as a basis for data collection and management policies. Implementation is expected to reveal additional opportunities to incentivize and ensure accurate data collection methods, such as an external auditing process.

Development of profiles for underrepresented materials and processes should be the first priority in developing Steelcase-specific data through the company's broader IT initiative. The case studies discussed in Section 6.0, and particularly the study focused on the Garland product, indicate that some materials are underrepresented in SimaPro. These materials should be the focus of initial efforts to improve data availability. Internal average profiles for materials that are currently underrepresented in generic data sources could be particularly valuable in filling this gap and increasing the accuracy of early stage results.

Additional case studies based on products in development should be developed as Steelcase product developers begin to use the tool in order to refine expectations for data accuracy. Production of case studies in parallel with real-time product development will provide substantial supplemental examples of data accuracy. Over time, these additional case studies will build upon the simulations included in this initial research and verify expected levels of accuracy at each stage of product development.

Appendices

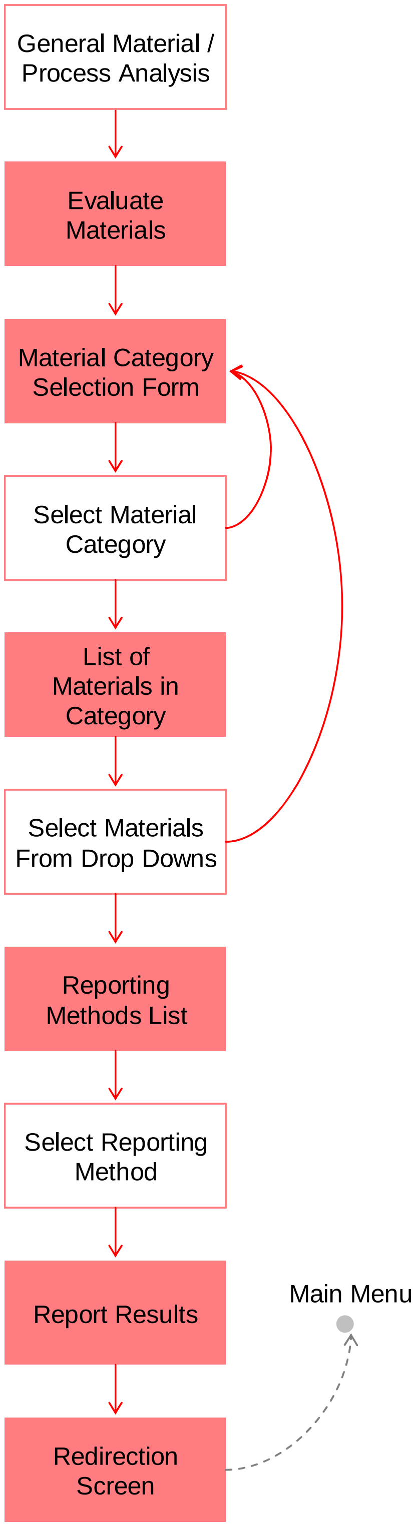
A. Wizard Commands

These commands are used in the SimaPro wizard coding process to build interfaces that can be used to make choices, build product profiles, add materials and processes, and report on environmental impacts. Text and images from *SimaPro 7: Wizards Manual.* PRé Consultants. 2007. www.pre.nl/download/manuals/WizardManual.pdf. Last accessed April 2008.

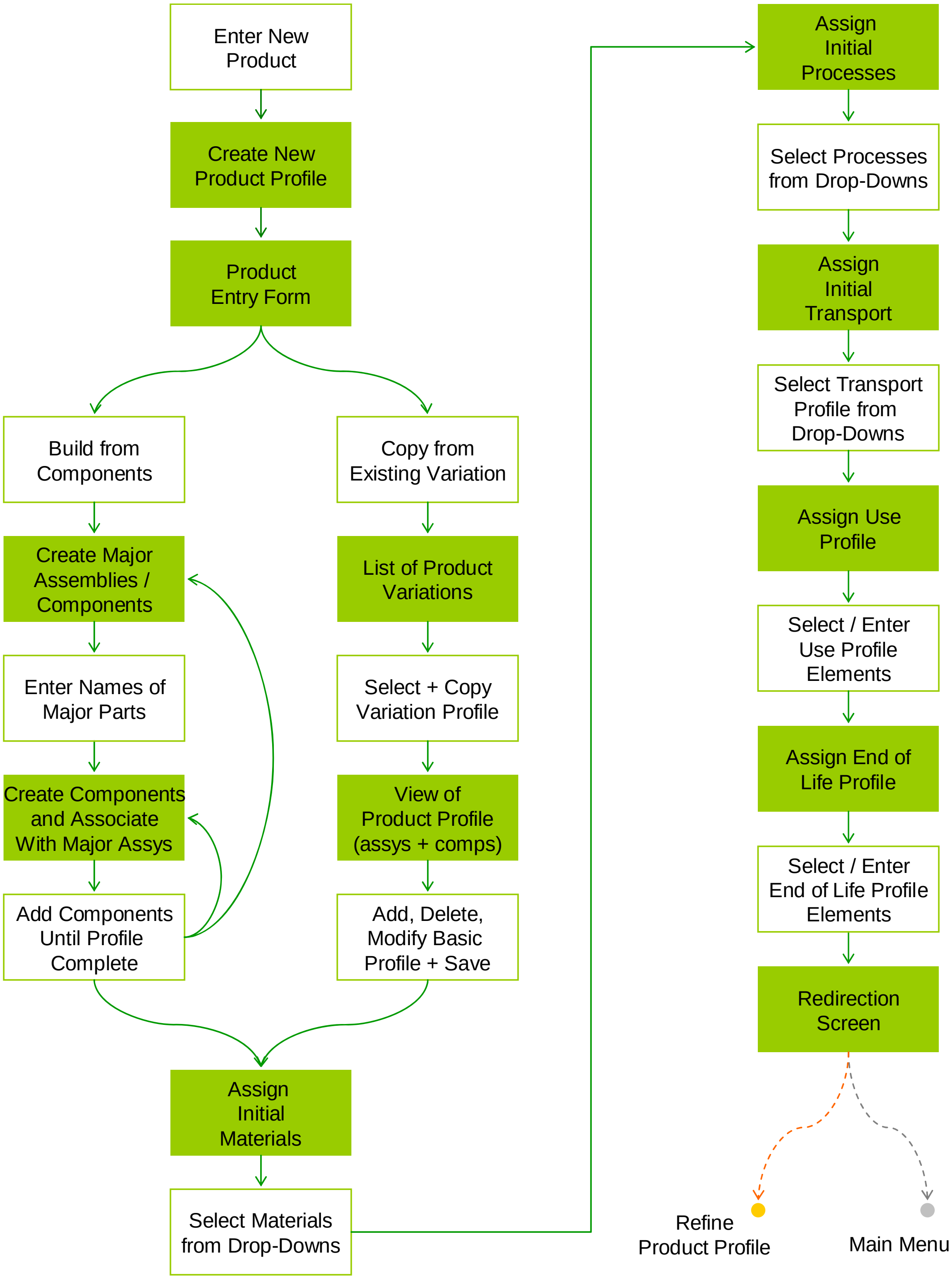
Message	**Message node** Displays a text message to the user.
Enter name	**Enter name node** Allows the user to enter a name; for example the name of an assembly.
Enter values	**Enter values node** Allows the user to enter a value; for example the amount of steel in an assembly.
Select process/product stage	**Select process node** Allows the user to select a process into an assembly; for example, he can choose between the different types of steel in the database**.**
● A ○ B Choose	**Choose wizard route node** Allows the user to decide which is the next task.
Call	**Call wizard node** Jumps to and activates another wizard.
1 + 1 Calculate	**Calculate node** Calculates the results of one or more processes or product stages with an impact assessment method.
Operations	**Operations node** This is one of the most complex and advanced nodes. Here you can create new processes and product stages. It allows you to include arithmetic operations within the wizard. For example, you ask the user for the height and width, and you let the operation node calculate the surface.
Show inventory	**Show inventory node** Lets SimaPro show the Life cycle inventory results or results of impact assessment per substance.
Show impact assessment	**Show impact assessment node** Lets SimaPro show the results of impact assessment in a predefined way.
Show network	**Show network node** Lets SimaPro display a graphical process network representation.

B. WELE Pathway Decision Steps

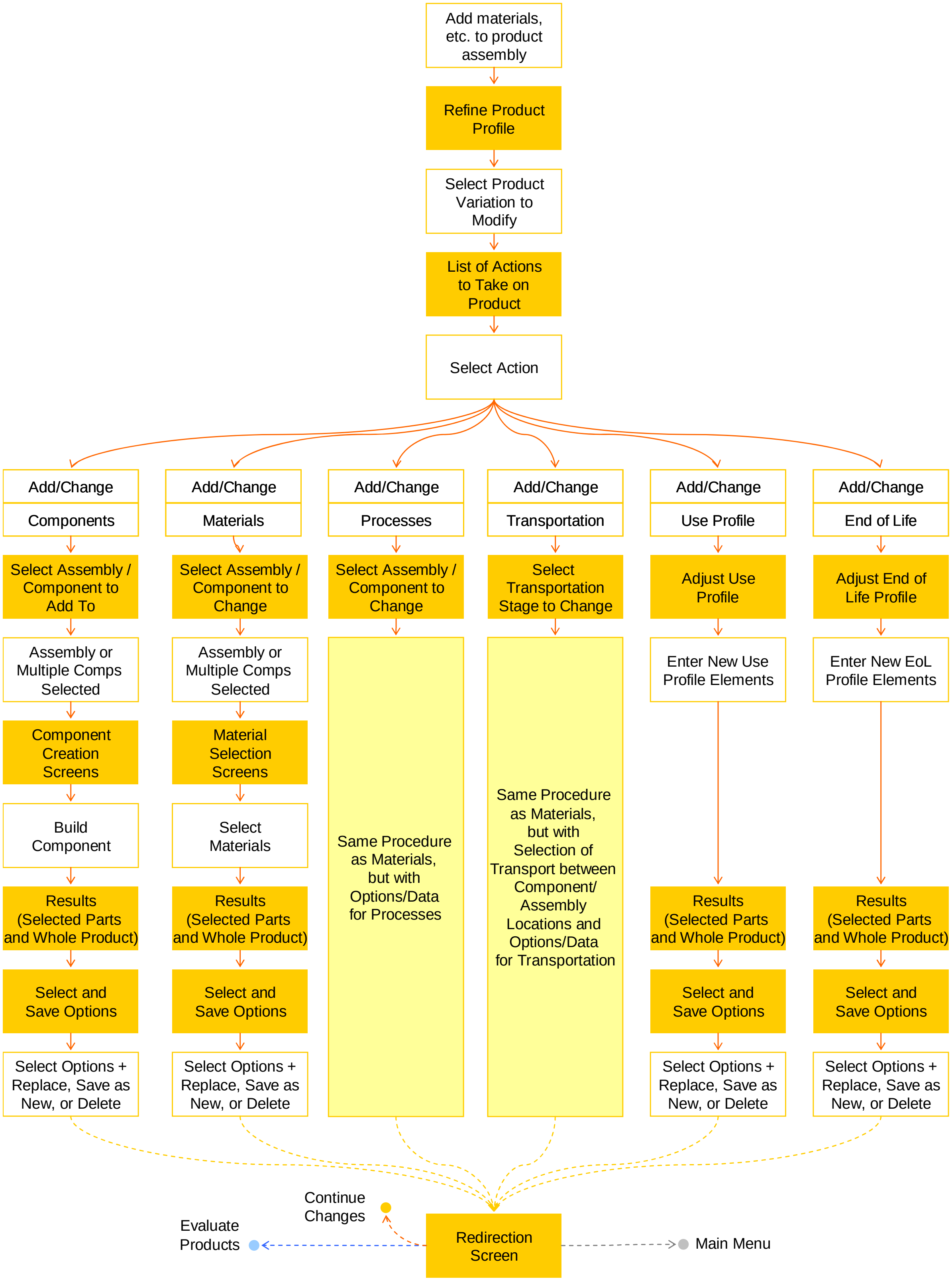
Evaluate Materials



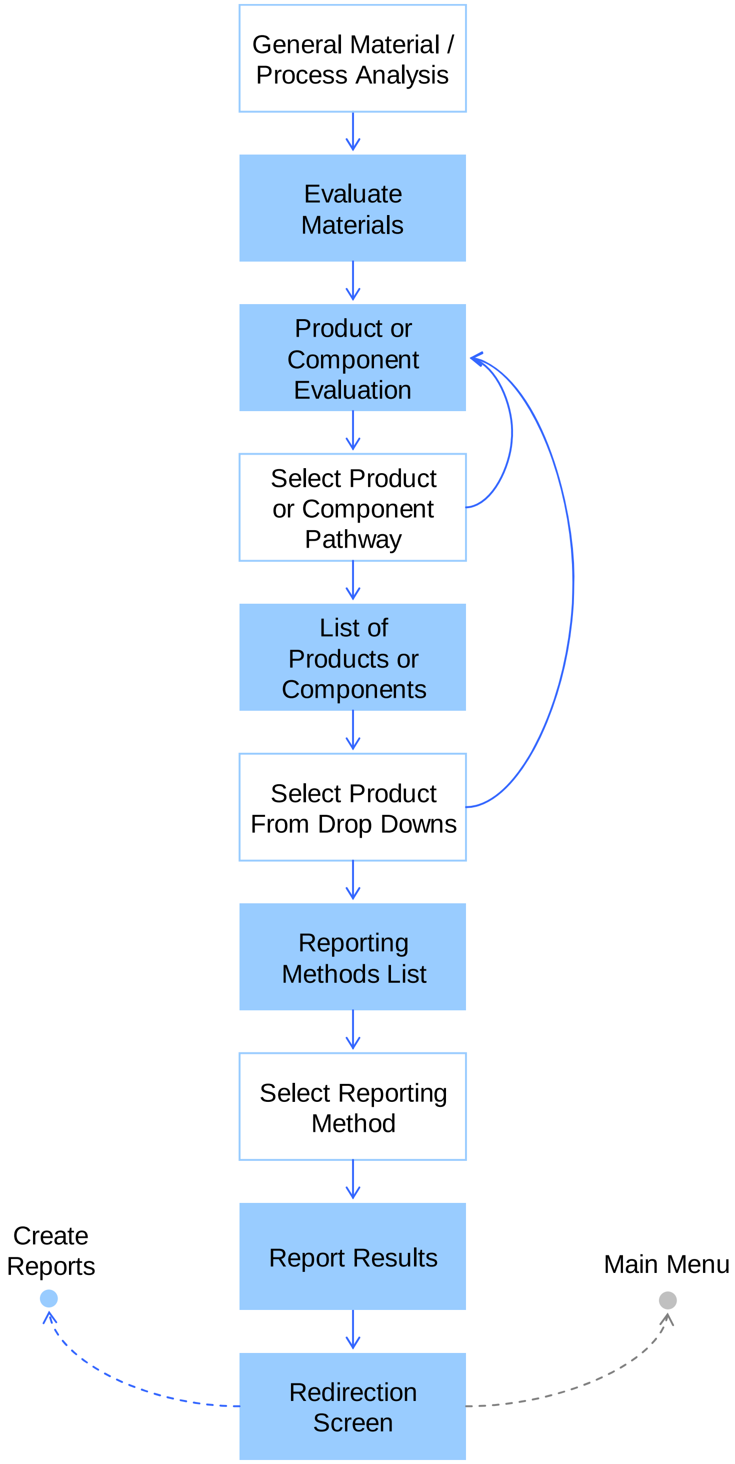
Create New Product Profile



Refine Product Profile



Evaluate Products



C. Usability Needs

SimaPro Needs: Prioritized List for Steelcase Wizards Tool

Needed Capability	Purpose
Allow users to save new product profiles to a specific location. Currently, any new profiles that are created are automatically saved to an "Other" folder and have to be moved manually.	The current situation requires users to go outside of the wizards process and follow extensive instructions to move new product elements to the appropriate folder (products and their subcomponents need to be in separate folders to show up on the wizard lists). Ideally would have integrated option to select where to store profiles or coding to automatically store elements in the appropriate folders.
Allow users to save reports. The "Product Systems" option does not allow comparisons, and it is not possible to save reports to the "Calculation Setups" feature when they are created through wizards.	Currently, reports created in the wizards can't be saved in SimaPro and users have to be instructed to save any results externally. Ideally, reports could automatically be saved to "Calculation Setups" similar to product profiles automatically saved to "Product Stages".
Allow users to copy existing profiles through the wizards.	Currently has to be done manually. Ideally would be able to duplicate a product profile (and its subcomponents) through the wizards.
Use a folder structure within the list feature (like Microsoft Office when opening documents). Currently, additional screens are needed to select a category and then redirect people to the list.	Would make selecting from lists more intuitive and cut out many screens. For example, when selecting materials would be able to go to the full list and open the metals folder, then the aluminum folder rather than clicking through multiple screens to get the same result.
Automatically include new sub-folders in list functions. Currently, if a sub-folder is created under a folder that shows up on a wizard list, the sub-folder's content will not automatically show up on the list.	A current limitation is that all products and sub-products have to be in one folder for new products to show up on wizard lists once they're created. Ideally would be able to organize products into subfolders and have these folders show up on wizard lists once they're created.
Allow combined "List" and "Choose" functions. Ideally allow inclusion of quantity selection function on the same screen as well.	Combining these two functions so users can pick from a list, then choose their next action. This would cut screen time in half.
In reporting, generate a full report rather than viewing predetermined sections on multiple screens.	Allow users to view the report in a single document (PDF, Excel) that can be viewed in full and saved outside of SimaPro.

Needed Capability	Purpose
Allow selection of reporting features in "design a report" function.	Allow users to include different types of charts in their reports based on the information they need most for different reporting.
Include additional reporting options.	Currently, reporting charts are limited to a few charts and lists. There are several types of reporting, particularly regarding MBDC criteria, which would be more intuitive with additional reporting options.
In material and process profiles, a "Rating" category to store MBDC / other rating data. Currently, data stored under "Economic Issues" to distinguish between "Red" and "Orange" materials).	Ideal is to list all materials with a red or orange color attributed to the material or "Red" or "Orange" listed next to it. Ideally have a category in material profiles where these text characterizations can be assigned and a reporting feature where they can be evaluated.
Recycled content and recyclability reporting. Currently does not appear to be feasible to implement.	Data on recycled content and recyclability could potentially be reported (sum of recycled content and a characterization of materials based on their typical recycling rates). This is not feasible within the current reporting options.
Provide split screen of wizard selection and profile display screens. Currently, users must click through to see the profile of the product / material they've selected.	This option would cut down on screen time and make the selection process more intuitive, as users could see the profile next to the wizard they're using to select / modify the profile.
Put hyperlinks into wizard text boxes (message, list, and choose functions).	Request from Steelcase users to be able to reference documents directly from within the wizards (e.g. user's manual).
Put images into wizard text boxes (message, list and choose functions).	Some references are made to actions on the following screen such as the "calculate" function. Ideally would be able to put an image of the needed icon in the message box so users know what to do on the next screen. Additional images would be useful in the tutorial – e.g. explaining the life cycle stages considered in analysis easier to display with an image.
Bold, italic, font size functions in text boxes (message, list, functions).	Would be useful in text boxes where there is a lot of instruction to separate sections of the text.
Exploration of CAD integration.	Connecting SimaPro data to CAD profiles would make the tool more usable for engineers during development activities.

D. Case Studies: Materials Included in Analysis

Airtouch: Steelcase and Generic Materials by Component

Component	Steelcase Material	Generic Material	Generic Source
3.4_Cap-End	Steelcase Cast Aluminum	Aluminum 80% rec. B250 *	BUWAL 250
2.1_Column-Worksurface	Steelcase Extruded Aluminum	Aluminum 25% rec. B250 **	BUWAL 250
2.2.1_Plate-Mounting	Steelcase Cast Aluminum	Aluminum 80% rec. B250 *	BUWAL 250
2.2.3_Cam	Steelcase Cast Aluminum	Aluminum 80% rec. B250 *	BUWAL 250
2.2.7_Guide	Steelcase Extruded Aluminum	Aluminum 25% rec. B250 **	BUWAL 250
2.2.9_Bracket	Steelcase Rolled Aluminum	Aluminum 25% rec. B250 ***	BUWAL 250

* Selection based on most comparable recycled content to that specified for Steelcase Cast Aluminum (85%)

** Selection based on most comparable recycled content to that specified for Steelcase Extruded Aluminum (11%)

*** Selection based on most comparable recycled content to that specified for Steelcase Rolled Aluminum (7%)

Garland: Steelcase and Generic Materials by Component

Component	Steelcase Material	Generic Material	Generic Source
4_WORKSURFACE RECTANGULAR	Particleboard to Grand Rapids	Particleboard, US	From BEES
4_WORKSURFACE RECTANGULAR	Cherry Veneer (final)	Cherry	Ash data from Europe
4_WORKSURFACE RECTANGULAR	Backer Laminate	Kraft Bleached FAL, US	Franklin USA 98
13_CLEAT ATTACHMENT	Poplar I, US	Poplar I	IDEMAT 2001
14_PIN DOWEL	Red oak I, US	Red Oak I	IDEMAT 2001
4.1_Nosing	Cherry Wood (final)	Cherry	Ash data from Europe
15.1_Headset Drawer	Particleboard to Grand Rapids	Particleboard, US	From BEES
15.1_Headset Drawer	Cherry Veneer (final)	Cherry	Ash data from Europe
15.2_FileBack	Particleboard to Grand Rapids	Particleboard, US	From BEES
15.2_FileBack	Cherry Veneer (final)	Cherry	Ash data from Europe

15.3_Base Wood	Particleboard to Grand Rapids	Particleboard, US	From BEES
15.3_Base Wood	Cherry Veneer (final)	Cherry	Ash data from Europe
15.4_Support WKSF,End	Particleboard to Grand Rapids	Particleboard, US	From BEES
15.4_Support WKSF,End	Cherry Veneer (final)	Cherry	Ash data from Europe
15.5_Panel Knee	Particleboard to Grand Rapids	Particleboard, US	From BEES
15.5_Panel Knee	Cherry Veneer (final)	Cherry	Ash data from Europe
15.27_Pin Dowel	Red oak I, US	Red Oak I	IDEMAT 2001
17.1_Headset Drawer	Particleboard to Grand Rapids	Particleboard, US	From BEES
17.1_Headset Drawer	Cherry Veneer (final)	Cherry	Ash data from Europe
17.2_FileBack	Particleboard to Grand Rapids	Particleboard, US	From BEES
17.2_FileBack	Cherry Veneer (final)	Cherry	Ash data from Europe
17.3_Base Wood	Particleboard to Grand Rapids	Particleboard, US	From BEES
17.3_Base Wood	Cherry Veneer (final)	Cherry	Ash data from Europe
17.4_Support WKSF,End	Particleboard to Grand Rapids	Particleboard, US	From BEES
17.4_Support WKSF,End	Cherry Veneer (final)	Cherry	Ash data from Europe
17.5_Panel Knee	Particleboard to Grand Rapids	Particleboard, US	From BEES
17.5_Panel Knee	Cherry Veneer (final)	Cherry	Ash data from Europe
17.30.4_Divider Drawer	Red oak I, US	Red Oak I	IDEMAT 2001
PACKAGING WOOD, US	PACKAGING WOOD, US	Wood board ETH U	ETH-ESU 98 unit processes
PACKAGING CARDBOARD, US	PACKAGING CARDBOARD, US	Corr cardboard new	BUWAL250
PACKAGING HONEYCOMB, US	PACKAGING HONEYCOMB, US	Corr cardboard new	BUWAL250
PACKAGING PAPER, US	PACKAGING PAPER, US	Kraftpaper unbleached	BUWAL250
PACKAGING STRETCH FOIL, US	PACKAGING STRETCH FOIL, US	LDPE Film FAL	Franklin USA 98

Slim Chair: Steelcase and Generic Materials by Component

Component	Steelcase Material	Generic Material	Generic Source
1.1.3_Pintle	IISI, Engineering Steel, EAF Route	Steel 23% recycled B	Data Archive
1.2_Base Polished	Steelcase Cast Aluminum	Aluminum 80% rec. B250 *	BUWAL 250
1.3_Pneumatic Cylinder	IISI, Engineering Steel, EAF Route	Steel 23% recycled B	Data Archive
2.1.5_PneuLever	IISI, Rebar, EAF Route	Steel 23% recycled B	Data Archive
2.1.11_BackLockLever	IISI, Rebar, EAF Route	Steel 23% recycled B	Data Archive
2.1.14.1_Seat PivotBracket	GS-10Ni6 I, US	Steel 23% recycled B	Data Archive
2.1.14.2_Bracket ArmPivot	GS-10Ni6 I, US	Steel 23% recycled B	Data Archive
2.2.1_ArmStrap Front	IISI, Finished Cold Rolled Coil, BF Route	Steel 23% recycled B	Data Archive
2.3.1_SupportPlate RearArmStrap	IISI, Finished Cold Rolled Coil, BF Route	Steel 23% recycled B	Data Archive
2.3.2.4_Strap Arm Type2	IISI, Finished Cold Rolled Coil, BF Route	Steel 23% recycled B	Data Archive
3.1.1_Housing Control Chair	IISI, Finished Cold Rolled Coil, BF Route	Steel 23% recycled B	Data Archive
3.1.2_SupportBushing	IISI, Finished Cold Rolled Coil, BF Route	Steel 23% recycled B	Data Archive
3.1.3_Bushing HousingTapered	IISI, Finished Cold Rolled Coil, BF Route	Steel 23% recycled B	Data Archive
3.2.1_Support Upright	IISI, Finished Cold Rolled Coil, BF Route	Steel 23% recycled B	Data Archive
3.2.2_Support PivotSynchro	IISI, Finished Cold Rolled Coil, BF Route	Steel 23% recycled B	Data Archive
3.4_Tube Axle	IISI, Steel Section, EAF Route	Steel 23% recycled B	Data Archive
3.5_Spring Torsion LeftHand	IISI, Rebar, EAF Route	Steel 23% recycled B	Data Archive
3.6_Spring Torsion RightHand	IISI, Rebar, EAF Route	Steel 23% recycled B	Data Archive
3.7_Bracket Spring Tension	IISI, Finished Cold Rolled Coil, BF Route	Steel 23% recycled B	Data Archive
3.8_Shaft Adjustment Tension Painted	IISI, Finished Cold Rolled Coil, BF Route	Steel 23% recycled B	Data Archive
3.9_Nut Adjustment Tension	IISI, Engineering Steel, EAF Route	Steel 23% recycled B	Data Archive
3.10_Plate Pivot Tension	IISI, Finished Cold Rolled Coil, BF Route	Steel 23% recycled B	Data Archive
4.1_Shell InnerSeat S	Polypropylene (PP)	PP injection moulded	Industry Data

	Injection Molding	A	
4.2_Shell OuterSeat	Polypropylene (PP) Injection Molding	PP injection moulded A	Industry Data
4.4_Foam Topper Seat	Polyurethane Flexible Foam	PUR flex. Block foam I	IDEMAT 2001
4.5_Foam Molded Seat	Polyurethane Flexible Foam	PUR flex. Block foam I	IDEMAT 2001
5.1_Tarm LH Polished	Steelcase Cast Aluminum	Aluminum 80% rec. B250 *	BUWAL 250
5.2_Tarm RH Polished	Steelcase Cast Aluminum	Aluminum 80% rec. B250 *	BUWAL 250
5.6_TArmCap Molded	Polyurethane Flexible Foam	PUR flex. Block foam I	IDEMAT 2001
5.6.1_TArmCapInner	Polypropylene (PP) Injection Molding	PP injection moulded A	Industry Data
6.1.1.2_Tube BackMounting	IISI, Steel Section, EAF Route	Steel 23% recycled B	Data Archive
6.1.1.3_Tube CrossStretcher	IISI, Steel Section, EAF Route	Steel 23% recycled B	Data Archive
6.1.1.4_Link LowerInner RH	GS-10Ni6 I, US	Steel 23% recycled B	Data Archive
6.1.1.5_Link LowerInner LH	GS-10Ni6 I, US	Steel 23% recycled B	Data Archive
6.1.1.6_Link LowerOuter	GS-10Ni6 I, US	Steel 23% recycled B	Data Archive
6.1.2.1_Link Inner RH	GS-10Ni6 I, US	Steel 23% recycled B	Data Archive
6.1.2.2_Link Inner LH	GS-10Ni6 I, US	Steel 23% recycled B	Data Archive
6.1.2.3_CrossMember Middle	IISI, Rebar, EAF Route	Steel 23% recycled B	Data Archive
6.1.2.4_CrossMember Lower	IISI, Rebar, EAF Route	Steel 23% recycled B	Data Archive
6.1.2.5_Flange InnerLink RH	GS-10Ni6 I, US	Steel 23% recycled B	Data Archive
6.1.2.6_Flange InnerLink LH	GS-10Ni6 I, US	Steel 23% recycled B	Data Archive
6.1.3.1_CrossMember Upper	IISI, Rebar, EAF Route	Steel 23% recycled B	Data Archive
6.1.3.3_BackWire	IISI, Rebar, EAF Route	Steel 23% recycled B	Data Archive
6.1.3.4_Link Upper Inner RH	GS-10Ni6 I, US	Steel 23% recycled B	Data Archive
6.1.3.5_Link Upper Inner LH	GS-10Ni6 I, US	Steel 23% recycled B	Data Archive
6.1.3.7_Link Upper Outer	IISI, Finished Cold Rolled Coil, BF Route	Steel 23% recycled B	Data Archive

6.1.3.8_Bracket InnerBack	GS-10Ni6 I, US	Steel 23% recycled B	Data Archive
6.1.7_Rivet Main	IISI, Engineering Steel, EAF Route	Steel 23% recycled B	Data Archive
6.1.9_Spring	IISI, Rebar, EAF Route	Steel 23% recycled B	Data Archive
6.1.12_Link Outer RH	GS-10Ni6 I, US	Steel 23% recycled B	Data Archive
6.1.13_Link Outer LH	GS-10Ni6 I, US	Steel 23% recycled B	Data Archive
6.1.14_Bracket InnerBack	GS-10Ni6 I, US	Steel 23% recycled B	Data Archive
7.1.1_Dimatrol	Polyester fabric I, SC	Polyester fabric I	IDEMAT 2001
7.1.3_Channel Side RH	Polypropylene (PP) Injection Molding	PP injection moulded A	Industry Data
7.1.4_Channel Side LH	Polypropylene (PP) Injection Molding	PP injection moulded A	Industry Data
7.1.5_Extrusion J Top	Polypropylene (PP) Injection Molding	PP injection moulded A	Industry Data
7.1.6_Extrusion J	Polypropylene (PP) Injection Molding	PP injection moulded A	Industry Data
7.3_Foam Topper HighBack	Polyurethane Flexible Foam	PUR flex. Block foam I	IDEMAT 2001
7.4_Foam HighBack Front	Polyurethane Flexible Foam	PUR flex. Block foam I	IDEMAT 2001
7.5_Foam HighBack Rear	Polyurethane Flexible Foam	PUR flex. Block foam I	IDEMAT 2001
8.1_Belt Inner	Polypropylene (PP) Injection Molding	PP injection moulded A	Industry Data
8.3_Belt Outer	Polypropylene (PP) Injection Molding	PP injection moulded A	Industry Data
8.5.1_Shell Back	Polypropylene (PP) Injection Molding	PP injection moulded A	Industry Data
PACKAGING CARDBOARD, US	PACKAGING CARDBOARD, US	Corrugated cardboard FAL	Franklin USA 98
PACKAGING PLASTIC BAG, US	PACKAGING PLASTIC BAG, US	LDPE Film FAL	Franklin USA 98

E. Case Studies: Individual Material Comparisons

Airtouch Individual Material Results Generic Data Steelcase Data

Cast Aluminum vs. 80% Recycled	80% Recycled	Cast Aluminum
ERC	73%	100%
GWP	55%	100%
AP	40%	100%
CP	23%	100%
SW	19%	100%
TMC	19%	100%

Rolled Aluminum vs. 25% Recycled	25% Recycled	Rolled Aluminum
ERC	76%	100%
GWP	52%	100%
AP	44%	100%
CP	19%	100%
SW	21%	100%
TMC	25%	100%

Extruded Aluminum vs. 25% Recycled	25% Recycled	Extruded Aluminum
ERC	78%	100%
GWP	54%	100%
AP	45%	100%
CP	19%	100%
SW	22%	100%
TMC	26%	100%

Garland Individual Material Results Generic Data Steelcase Data

Cherry Wood	Cherry	Cherry Wood (final)
ERC	44%	100%
GWP	39%	100%
AP	61%	100%
CP	67%	100%
SW	8%	100%
TMC	18%	100%

Cherry Veneer	Cherry	Cherry Veneer (final)
ERC	29%	100%
GWP	27%	100%
AP	30%	100%
CP	31%	100%
SW	5%	100%
TMC	14%	100%

Particleboard	Particleboard, US	Particleboard to GR
ERC	76%	100%
GWP	79%	100%
AP	46%	100%
CP	72%	100%
SW	1%	100%
TMC	100%	78%

Backer Laminate	Kraft Bleached, FAL	Backer Laminate
ERC	60%	100%
GWP	100%	76%
AP	55%	100%
CP	61%	100%
SW	100%	92%
TMC	100%	80%

Poplar	Poplar I	Poplar I, US
ERC	N/A	100%
GWP	2%	100%
AP	0%	100%
CP	N/A	100%
SW	0%	100%
TMC	100%	88%

Red Oak	Red Oak I	Red Oak I, US
ERC	64%	100%
GWP	67%	100%
AP	65%	100%
CP	60%	100%
SW	0%	100%
TMC	100%	62%

Packaging Wood	**Wood board ETH U**	**PACK WOOD, US**
ERC	N/A	100%
GWP	2%	100%
AP	1%	100%
CP	N/A	100%
SW	N/A	100%
TMC	100%	52%

Packaging Cardboard	**Corr cardboard new**	**PACK CBOARD, US**
ERC	N/A	100%
GWP	1%	100%
AP	1%	100%
CP	N/A	100%
SW	0%	100%
TMC	46%	100%

Packaging Honeycomb	**Corr cardboard new**	**PACK HONEY, US**
ERC	N/A	100%
GWP	1%	100%
AP	1%	100%
CP	N/A	100%
SW	0%	100%
TMC	46%	100%

Packaging Paper	**Kraftpaper unbleached**	**PACK PAPER, US**
ERC	N/A	100%
GWP	4%	100%
AP	0%	100%
CP	N/A	100%
SW	11%	100%
TMC	52%	100%

Packaging Foil	**LDPE Film FAL**	**PACK STRETCH FOIL, US**
ERC	45%	100%
GWP	100%	100%
AP	49%	100%
CP	50%	100%
SW	72%	100%
TMC	100%	100%

Slim Chair Individual Material Results Generic Data Steelcase Data

PP Injection	PP injection moulded A	Polypropylene (PP) Injection Molding
ERC	46%	100%
GWP	98%	100%
AP	37%	100%
CP	40%	100%
SW	27%	100%
TMC	78%	100%

Polyurethane	PUR flex. Block foam I	Polyurethane Flexible Foam
ERC	23%	100%
GWP	1%	100%
AP	4%	100%
CP	1%	100%
SW	100%	46%
TMC	100%	93%

Polyester	Polyester fabric I	Polyester fabric I, SC
ERC	11%	100%
GWP	1%	100%
AP	1%	100%
CP	0%	100%
SW	54%	100%
TMC	100%	70%

Cast Aluminum	Aluminum 80% rec. B250 *	Steelcase Cast Aluminum
ERC	73%	100%
GWP	55%	100%
AP	40%	100%
CP	23%	100%
SW	19%	100%
TMC	48%	100%

Packaging Cardboard	Corrugated cardboard FAL	PACKAGING CARDBOARD, US
ERC	N/A	100%
GWP	1%	100%
AP	1%	100%
CP	N/A	100%
SW	0%	100%
TMC	46%	100%

Packaging Plastic	LDPE Film FAL	PACKAGING PLASTIC BAG, US
ERC	45%	100%
GWP	100%	100%
AP	49%	100%
CP	50%	100%
SW	72%	100%
TMC	100%	100%

Engineering Steel	Steel 23% recycled B	IISI, Engineering Steel, EAF Route
ERC	100%	32%
GWP	100%	28%
AP	100%	42%
CP	100%	52%
SW	100%	43%
TMC	71%	100%

Rebar Steel	Steel 23% recycled B	IISI, Rebar, EAF Route
ERC	100%	23%
GWP	100%	18%
AP	100%	33%
CP	100%	38%
SW	100%	2%
TMC	100%	60%

GS-10Ni6	**Steel 23% recycled B**	**GS-10Ni6 I, US**
ERC	100%	29%
GWP	100%	17%
AP	100%	26%
CP	100%	21%
SW	100%	0%
TMC	52%	100%

Cold Rolled Steel	**Steel 23% recycled B**	**IISI, Finished Cold Rolled Coil, BF Route**
ERC	100%	85%
GWP	96%	100%
AP	100%	66%
CP	77%	100%
SW	23%	100%
TMC	64%	100%

Steel Section	**Steel 23% recycled B**	**IISI, Steel Section, EAF Route**
ERC	100%	17%
GWP	100%	19%
AP	100%	17%
CP	100%	27%
SW	100%	24%
TMC	89%	100%

F. Case Studies: Material Comparisons in Product Profiles

Airtouch Component/Product Results Generic Data Steelcase Data

Base Table: Cast Aluminum vs. 80% Recycled	**80% Recycled**	**Cast Aluminum**
ERC	96%	100%
GWP	97%	100%
AP	94%	100%
CP	93%	100%
SW	97%	100%
TMC	99%	100%

Column: Multiple Aluminum Profiles	**Generic Aluminums**	**Steelcase Aluminums**
ERC	70%	100%
GWP	76%	100%
AP	65%	100%
CP	63%	100%
SW	81%	100%
TMC	100%	89%

Airtouch Full	**Generic**	**Steelcase**
ERC	77%	100%
GWP	82%	100%
AP	73%	100%
CP	69%	100%
SW	86%	100%
TMC	100%	94%

Garland Component/Product Results Generic Data Steelcase Data

4_WORKSURFACE RECTANGULAR	**Generic**	**Steelcase**
ERC	87%	100%
GWP	90%	100%
AP	74%	100%
CP	86%	100%
SW	46%	100%
TMC	98%	100%

13_CLEAT ATTACHMENT	**Generic**	**Steelcase**
ERC	N/A	100%
GWP	2%	100%
AP	0%	100%
CP	N/A	100%
SW	0%	100%
TMC	100%	88%

14_PIN DOWEL	**Generic**	**Steelcase**
ERC	64%	100%
GWP	67%	100%
AP	65%	100%
CP	60%	100%
SW	0%	100%
TMC	100%	62%

15.1_Headset Drawer	**Generic**	**Steelcase**
ERC	90%	100%
GWP	92%	100%
AP	79%	100%
CP	89%	100%
SW	55%	100%
TMC	100%	94%

15.2_FileBack	**Generic**	**Steelcase**
ERC	73%	100%
GWP	74%	100%
AP	46%	100%
CP	70%	100%
SW	2%	100%
TMC	100%	89%

15.3_Base Wood	**Generic**	**Steelcase**
ERC	73%	100%
GWP	74%	100%
AP	46%	100%
CP	71%	100%
SW	2%	100%
TMC	100%	98%

15.4_Support WKSF,End	**Generic**	**Steelcase**
ERC	83%	100%
GWP	85%	100%
AP	65%	100%
CP	82%	100%
SW	30%	100%
TMC	100%	87%

15.5_Panel Knee	**Generic**	**Steelcase**
ERC	82%	100%
GWP	84%	100%
AP	64%	100%
CP	81%	100%
SW	28%	100%
TMC	100%	86%

15.27_Pin Dowel	**Generic**	**Steelcase**
ERC	64%	100%
GWP	67%	100%
AP	65%	100%
CP	60%	100%
SW	0%	100%
TMC	100%	62%

File Ped 15 Full	**Generic**	**Steelcase**
ERC	89%	100%
GWP	92%	100%
AP	73%	100%
CP	86%	100%
SW	79%	100%
TMC	100%	98%

17.1_Headset Drawer	**Generic**	**Steelcase**
ERC	91%	100%
GWP	92%	100%
AP	80%	100%
CP	90%	100%
SW	57%	100%
TMC	100%	94%

17.2_FileBack	**Generic**	**Steelcase**
ERC	84%	100%
GWP	86%	100%
AP	66%	100%
CP	82%	100%
SW	32%	100%
TMC	100%	92%

17.3_Base Wood	**Generic**	**Steelcase**
ERC	87%	100%
GWP	89%	100%
AP	74%	100%
CP	86%	100%
SW	45%	100%
TMC	100%	98%

17.4_Support WKSF,End	**Particleboard, US**	**Particleboard to GR**
ERC	83%	100%
GWP	85%	100%
AP	65%	100%
CP	82%	100%
SW	30%	100%
TMC	100%	87%

17.5_Panel Knee	**Kraft Bleached, FAL**	**Backer Laminate**
ERC	82%	100%
GWP	84%	100%
AP	64%	100%
CP	81%	100%
SW	28%	100%
TMC	100%	86%

17.30.4_Divider Drawer	**Generic**	**Steelcase**
ERC	64%	100%
GWP	67%	100%
AP	65%	100%
CP	60%	100%
SW	0%	100%
TMC	100%	62%

File Ped 17 Full	**Generic**	**Steelcase**
ERC	90%	100%
GWP	93%	100%
AP	75%	100%
CP	87%	100%
SW	79%	100%
TMC	100%	98%

Full Garland	**Generic**	**Steelcase**
ERC	85%	100%
GWP	87%	100%
AP	70%	100%
CP	81%	100%
SW	68%	100%
TMC	91%	100%

Pkg Impacts on Full Garland	**Generic**	**Steelcase**
ERC	95%	100%
GWP	94%	100%
AP	93%	100%
CP	92%	100%
SW	97%	100%
TMC	100%	98%

Cherry Wood Impacts on Full Garland	**Generic**	**Steelcase**
ERC	99%	100%
GWP	99%	100%
AP	100%	100%
CP	100%	100%
SW	96%	100%
TMC	98%	100%

Cherry Veneer Impacts on Full Garland	**Generic**	**Steelcase**
ERC	99%	100%
GWP	99%	100%
AP	99%	100%
CP	99%	100%
SW	94%	100%
TMC	97%	100%

Particleboard Impacts on Full Garland	**Generic**	**Steelcase**
ERC	92%	100%
GWP	95%	100%
AP	80%	100%
CP	90%	100%
SW	82%	100%
TMC	93%	100%

Laminate Impacts on Full Garland	**Generic**	**Steelcase**
ERC	99%	100%
GWP	100%	100%
AP	99%	100%
CP	99%	100%
SW	100%	100%
TMC	100%	100%

Poplar Impacts on Full Garland	**Generic**	**Steelcase**
ERC	100%	100%
GWP	100%	100%
AP	100%	100%
CP	100%	100%
SW	100%	100%
TMC	100%	100%

Red Oak Impacts on Full Garland	**Generic**	**Steelcase**
ERC	100%	100%
GWP	100%	100%
AP	100%	100%
CP	100%	100%
SW	100%	100%
TMC	100%	100%

Slim Chair Component/Product Results Generic Data Steelcase Data

1.2_Base Polished	**Generic**	**Steelcase**
ERC	73%	100%
GWP	55%	100%
AP	40%	100%
CP	23%	100%
SW	19%	100%
TMC	56%	100%

Base Casters Full - No Steel	**Generic**	**Steelcase**
ERC	84%	100%
GWP	80%	100%
AP	69%	100%
CP	52%	100%
SW	34%	100%
TMC	81%	100%

1.1.3_Pintle	**Generic**	**Steelcase**
ERC	100%	35%
GWP	100%	31%
AP	100%	48%
CP	100%	58%
SW	100%	45%
TMC	100%	83%

1.3_Pneumatic Cylinder	**Generic**	**Steelcase**
ERC	100%	32%
GWP	100%	28%
AP	100%	43%
CP	100%	53%
SW	100%	54%
TMC	100%	29%

Base Casters Full	**Generic**	**Steelcase**
ERC	93%	100%
GWP	91%	100%
AP	72%	100%
CP	54%	100%
SW	39%	100%
TMC	100%	87%

2.1.5_PneuLever	Generic	Steelcase
ERC	100%	27%
GWP	100%	21%
AP	100%	39%
CP	100%	46%
SW	100%	5%
TMC	80%	100%

2.1.11_BackLockLever	Generic	Steelcase
ERC	100%	27%
GWP	100%	21%
AP	100%	39%
CP	100%	46%
SW	100%	5%
TMC	80%	100%

2.1.14.1_SeatPivotBracket	Generic	Steelcase
ERC	86%	100%
GWP	87%	100%
AP	26%	100%
CP	24%	100%
SW	100%	98%
TMC	90%	100%

2.1.14.2_Bracket ArmPivot	Generic	Steelcase
ERC	86%	100%
GWP	87%	100%
AP	26%	100%
CP	24%	100%
SW	100%	98%
TMC	90%	100%

2.2.1_ArmStrap Front	Generic	Steelcase
ERC	89%	100%
GWP	100%	74%
AP	45%	100%
CP	27%	100%
SW	41%	100%
TMC	100%	58%

2.3.1_SupportPlate RearArmStrap	**Generic**	**Steelcase**
ERC	100%	85%
GWP	96%	100%
AP	100%	67%
CP	77%	100%
SW	24%	100%
TMC	63%	100%

2.3.2.4_Strap Arm Type2	**Generic**	**Steelcase**
ERC	100%	85%
GWP	96%	100%
AP	100%	67%
CP	77%	100%
SW	23%	100%
TMC	84%	100%

3.1.1_Housing Control Chair	**Generic**	**Steelcase**
ERC	100%	85%
GWP	96%	100%
AP	100%	67%
CP	77%	100%
SW	23%	100%
TMC	84%	100%

3.1.2_SupportBushing	**Generic**	**Steelcase**
ERC	100%	85%
GWP	96%	100%
AP	100%	68%
CP	78%	100%
SW	23%	100%
TMC	64%	100%

3.1.3_Bushing HousingTapered	**Generic**	**Steelcase**
ERC	100%	86%
GWP	96%	100%
AP	100%	74%
CP	82%	100%
SW	25%	100%
TMC	66%	100%

3.2.1_Support Upright	**Generic**	**Steelcase**
ERC	100%	85%
GWP	96%	100%
AP	100%	67%
CP	77%	100%
SW	23%	100%
TMC	84%	100%

3.2.2_Support PivotSynchro	**Generic**	**Steelcase**
ERC	100%	87%
GWP	96%	100%
AP	100%	77%
CP	84%	100%
SW	26%	100%
TMC	17%	100%

3.4_Tube Axle	**Generic**	**Steelcase**
ERC	100%	21%
GWP	100%	21%
AP	100%	24%
CP	100%	35%
SW	100%	79%
TMC	100%	70%

3.5_Spring Torsion LeftHand	**Generic**	**Steelcase**
ERC	100%	27%
GWP	100%	21%
AP	100%	39%
CP	100%	46%
SW	100%	5%
TMC	100%	63%

3.6_Spring Torsion RightHand	**Generic**	**Steelcase**
ERC	100%	27%
GWP	100%	21%
AP	100%	39%
CP	100%	46%
SW	100%	5%
TMC	100%	63%

3.7_Bracket Spring Tension	**Generic**	**Steelcase**
ERC	100%	85%
GWP	96%	100%
AP	100%	66%
CP	77%	100%
SW	23%	100%
TMC	63%	100%

3.8_Shaft Adjustment Tension Painted	**Generic**	**Steelcase**
ERC	100%	85%
GWP	96%	100%
AP	100%	69%
CP	79%	100%
SW	51%	100%
TMC	68%	100%

3.9_Nut Adjustment Tension	**Generic**	**Steelcase**
ERC	100%	32%
GWP	100%	28%
AP	100%	42%
CP	100%	52%
SW	100%	43%
TMC	100%	82%

3.10_Plate Pivot Tension	**Generic**	**Steelcase**
ERC	100%	85%
GWP	96%	100%
AP	100%	70%
CP	79%	100%
SW	24%	100%
TMC	64%	100%

CC Arm Full	**Generic**	**Steelcase**
ERC	100%	74%
GWP	100%	86%
AP	100%	52%
CP	100%	83%
SW	35%	100%
TMC	100%	49%

4.1_Shell InnerSeat S	**Generic**	**Steelcase**
ERC	100%	46%
GWP	100%	98%
AP	100%	37%
CP	100%	40%
SW	100%	27%
TMC	100%	78%

4.2_Shell OuterSeat	**Generic**	**Steelcase**
ERC	100%	46%
GWP	100%	98%
AP	100%	37%
CP	100%	40%
SW	100%	27%
TMC	100%	78%

4.4_Foam Topper Seat	**Generic**	**Steelcase**
ERC	23%	100%
GWP	1%	100%
AP	4%	100%
CP	1%	100%
SW	100%	46%
TMC	70%	100%

4.5_Foam Molded Seat	**Generic**	**Steelcase**
ERC	23%	100%
GWP	1%	100%
AP	4%	100%
CP	1%	100%
SW	100%	46%
TMC	100%	93%

Seat Full	**Generic**	**Steelcase**
ERC	100%	66%
GWP	69%	100%
AP	100%	67%
CP	100%	74%
SW	100%	74%
TMC	100%	73%

5.1_Tarm LH Polished	**Generic**	**Steelcase**
ERC	73%	100%
GWP	55%	100%
AP	40%	100%
CP	23%	100%
SW	19%	100%
TMC	26%	100%

5.2_Tarm RH Polished	**Generic**	**Steelcase**
ERC	73%	100%
GWP	55%	100%
AP	40%	100%
CP	23%	100%
SW	19%	100%
TMC	26%	100%

5.6_TArmCap Molded	**Generic**	**Steelcase**
ERC	92%	100%
GWP	85%	100%
AP	85%	100%
CP	84%	100%
SW	100%	64%
TMC	91%	100%

5.6.1_TArmCapInner	**Generic**	**Steelcase**
ERC	100%	46%
GWP	100%	98%
AP	100%	37%
CP	100%	40%
SW	100%	27%
TMC	45%	100%

Arms Full	**Generic**	**Steelcase**
ERC	84%	100%
GWP	61%	100%
AP	51%	100%
CP	29%	100%
SW	26%	100%
TMC	100%	67%

6.1.1.2_Tube BackMounting	**Generic**	**Steelcase**
ERC	100%	29%
GWP	100%	27%
AP	100%	37%
CP	100%	49%
SW	100%	52%
TMC	100%	67%

6.1.1.3_Tube CrossStretcher	**Generic**	**Steelcase**
ERC	100%	22%
GWP	100%	22%
AP	100%	25%
CP	100%	36%
SW	100%	27%
TMC	90%	100%

6.1.1.4_Link LowerInner RH	**Generic**	**Steelcase**
ERC	86%	100%
GWP	87%	100%
AP	26%	100%
CP	24%	100%
SW	100%	98%
TMC	90%	100%

6.1.1.5_Link LowerInner LH	**Generic**	**Steelcase**
ERC	86%	100%
GWP	87%	100%
AP	26%	100%
CP	24%	100%
SW	100%	98%
TMC	90%	100%

6.1.1.6_Link LowerOuter	**Generic**	**Steelcase**
ERC	86%	100%
GWP	87%	100%
AP	26%	100%
CP	24%	100%
SW	100%	98%
TMC	90%	100%

6.1.2.1_Link Inner RH	**Generic**	**Steelcase**
ERC	86%	100%
GWP	87%	100%
AP	26%	100%
CP	24%	100%
SW	100%	98%
TMC	94%	100%

6.1.2.2_Link Inner LH	**Generic**	**Steelcase**
ERC	86%	100%
GWP	87%	100%
AP	26%	100%
CP	24%	100%
SW	100%	98%
TMC	94%	100%

6.1.2.3_CrossMember Middle	**Generic**	**Steelcase**
ERC	100%	27%
GWP	100%	21%
AP	100%	39%
CP	100%	46%
SW	100%	5%
TMC	80%	100%

6.1.2.4_CrossMember Lower	**Generic**	**Steelcase**
ERC	100%	27%
GWP	100%	21%
AP	100%	39%
CP	100%	46%
SW	100%	5%
TMC	80%	100%

6.1.2.5_Flange InnerLink RH	**Generic**	**Steelcase**
ERC	86%	100%
GWP	87%	100%
AP	26%	100%
CP	24%	100%
SW	100%	98%
TMC	90%	100%

6.1.2.6_Flange InnerLink LH	**Generic**	**Steelcase**
ERC	86%	100%
GWP	87%	100%
AP	26%	100%
CP	24%	100%
SW	100%	98%
TMC	90%	100%

6.1.3.1_CrossMember Upper	**Generic**	**Steelcase**
ERC	100%	27%
GWP	100%	21%
AP	100%	39%
CP	100%	46%
SW	100%	5%
TMC	80%	100%

6.1.3.3_BackWire	**Generic**	**Steelcase**
ERC	100%	27%
GWP	100%	21%
AP	100%	39%
CP	100%	46%
SW	100%	5%
TMC	100%	17%

6.1.3.4_Link Upper Inner RH	**Generic**	**Steelcase**
ERC	86%	100%
GWP	87%	100%
AP	26%	100%
CP	24%	100%
SW	100%	98%
TMC	90%	100%

6.1.3.5_Link Upper Inner LH	**Generic**	**Steelcase**
ERC	86%	100%
GWP	87%	100%
AP	26%	100%
CP	24%	100%
SW	100%	98%
TMC	90%	100%

6.1.3.7_Link Upper Outer	**Generic**	**Steelcase**
ERC	100%	85%
GWP	96%	100%
AP	100%	67%
CP	77%	100%
SW	24%	100%
TMC	64%	100%

6.1.3.8_Bracket InnerBack	**Generic**	**Steelcase**
ERC	86%	100%
GWP	87%	100%
AP	26%	100%
CP	24%	100%
SW	100%	98%
TMC	90%	100%

6.1.7_Rivet Main	**Generic**	**Steelcase**
ERC	100%	35%
GWP	100%	31%
AP	100%	48%
CP	100%	58%
SW	100%	45%
TMC	100%	7%

6.1.9_Spring	**Generic**	**Steelcase**
ERC	100%	27%
GWP	100%	21%
AP	100%	39%
CP	100%	46%
SW	100%	5%
TMC	79%	100%

6.1.12_Link Outer RH	**Generic**	**Steelcase**
ERC	86%	100%
GWP	87%	100%
AP	26%	100%
CP	24%	100%
SW	100%	98%
TMC	90%	100%

6.1.13_Link Outer LH	**Generic**	**Steelcase**
ERC	86%	100%
GWP	87%	100%
AP	26%	100%
CP	24%	100%
SW	100%	98%
TMC	90%	100%

6.1.14_Bracket InnerBack	**Generic**	**Steelcase**
ERC	86%	100%
GWP	87%	100%
AP	26%	100%
CP	24%	100%
SW	100%	98%
TMC	90%	100%

Back Mech Full	**Generic**	**Steelcase**
ERC	100%	73%
GWP	100%	71%
AP	49%	100%
CP	45%	100%
SW	100%	69%
TMC	100%	80%

7.1.1_Dimatrol	**Generic**	**Steelcase**
ERC	11%	100%
GWP	1%	100%
AP	1%	100%
CP	0%	100%
SW	54%	100%
TMC	100%	88%

7.1.3_Channel Side RH	**Generic**	**Steelcase**
ERC	100%	46%
GWP	100%	98%
AP	100%	37%
CP	100%	40%
SW	100%	27%
TMC	45%	100%

7.1.4_Channel Side LH	**Generic**	**Steelcase**
ERC	100%	46%
GWP	100%	98%
AP	100%	37%
CP	100%	40%
SW	100%	27%
TMC	45%	100%

7.1.5_Extrusion J Top	**Generic**	**Steelcase**
ERC	100%	46%
GWP	100%	98%
AP	100%	37%
CP	100%	40%
SW	100%	27%
TMC	45%	100%

7.1.6_Extrusion J	**Generic**	**Steelcase**
ERC	100%	46%
GWP	100%	98%
AP	100%	37%
CP	100%	40%
SW	100%	27%
TMC	45%	100%

7.3_Foam Topper HighBack	**Generic**	**Steelcase**
ERC	23%	100%
GWP	1%	100%
AP	4%	100%
CP	1%	100%
SW	100%	46%
TMC	35%	100%

7.4_Foam HighBack Front	**Generic**	**Steelcase**
ERC	23%	100%
GWP	1%	100%
AP	4%	100%
CP	1%	100%
SW	100%	46%
TMC	100%	68%

7.5_Foam HighBack Rear	**Generic**	**Steelcase**
ERC	23%	100%
GWP	1%	100%
AP	4%	100%
CP	1%	100%
SW	100%	46%
TMC	100%	68%

Back Upholstery Full	**Generic**	**Steelcase**
ERC	61%	100%
GWP	35%	100%
AP	48%	100%
CP	56%	100%
SW	100%	84%
TMC	100%	89%

8.1_Belt Inner	**Generic**	**Steelcase**
ERC	100%	46%
GWP	100%	98%
AP	100%	37%
CP	100%	40%
SW	100%	27%
TMC	45%	100%

8.3_Belt Outer	**Generic**	**Steelcase**
ERC	100%	46%
GWP	100%	98%
AP	100%	37%
CP	100%	40%
SW	100%	27%
TMC	45%	100%

8.5.1_Shell Back	**Generic**	**Steelcase**
ERC	100%	46%
GWP	100%	98%
AP	100%	37%
CP	100%	40%
SW	100%	27%
TMC	23%	100%

Slim Chair Full	**Generic**	**Steelcase**
ERC	100%	91%
GWP	89%	100%
AP	85%	100%
CP	70%	100%
SW	60%	100%
TMC	100%	84%

Alum Impacts on Full Product	**Generic**	**Steelcase**
ERC	93%	100%
GWP	92%	100%
AP	86%	100%
CP	76%	100%
SW	72%	100%
TMC	96%	100%

PP Injection Impacts on Full Product	**Generic**	**Steelcase**
ERC	100%	87%
GWP	100%	100%
AP	100%	89%
CP	100%	94%
SW	100%	98%
TMC	100%	97%

Polyurethane Impacts on Full Product	**Generic**	**Steelcase**
ERC	94%	100%
GWP	90%	100%
AP	94%	100%
CP	96%	100%
SW	100%	97%
TMC	96%	100%

Polyester Impacts on Full Product	**Generic**	**Steelcase**
ERC	98%	100%
GWP	98%	100%
AP	98%	100%
CP	99%	100%
SW	100%	100%
TMC	100%	100%

Packaging Impacts on Full Product	Generic	Steelcase
ERC	98%	100%
GWP	100%	100%
AP	98%	100%
CP	99%	100%
SW	100%	100%
TMC	100%	100%

Steel Impacts on Full Product	Generic	Steelcase
ERC	100%	91%
GWP	100%	92%
AP	97%	100%
CP	94%	100%
SW	83%	100%
TMC	100%	81%

G. Case Studies: Processes Included in Analysis

Airtouch: Steelcase and Generic Processes by Component

Component	Steelcase Processes	Generic Processes	Generic Data Source
A. BASE TABLE	Drilling steel, US (hours)	Machining Steel, US	Kemna
A. BASE TABLE	Hand tool, electric, SC (hours)	Electricity avg. kWh USA	IDEMAT 2001
A. BASE TABLE	Welding, MIG SC (hours)	Electric MIG welding 4 l	IDEMAT 2001
B. COLUMN	Linear drive system, SC (hours)	Electricity avg. kWh USA	Kemna
B. COLUMN	Hand tool, pneumatic (hours)	Electricity avg. kWh USA	IDEMAT 2001
B. COLUMN	TOTAL	TOTAL	

Garland: Steelcase and Generic Processes by Component

Component	Steelcase Processes	Generic Processes	Generic Data Source
4_WORKSURFACE RECTANGULAR	CNC router (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
4_WORKSURFACE RECTANGULAR	CNC router (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
4_WORKSURFACE RECTANGULAR	CNC router (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
4_WORKSURFACE RECTANGULAR	Finishing (finishing line), SC	Electricity avg. kWh USA	IDEMAT 2001
4_WORKSURFACE RECTANGULAR	Finishing (finishing line), SC	Electricity avg. kWh USA	IDEMAT 2001
4_WORKSURFACE RECTANGULAR	Finishing (finishing line), SC	Electricity avg. kWh USA	IDEMAT 2001
4_WORKSURFACE RECTANGULAR	Finishing (finishing line), SC	Electricity avg. kWh USA	IDEMAT 2001
4_WORKSURFACE RECTANGULAR	Hand tool, electric	Electricity avg. kWh USA	IDEMAT 2001
4_WORKSURFACE RECTANGULAR	Hot-laminating press (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
4_WORKSURFACE RECTANGULAR	Hot-laminating press (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
4_WORKSURFACE RECTANGULAR	Single edge bander, SC	Electricity avg. kWh USA	IDEMAT 2001
4_WORKSURFACE RECTANGULAR	Splicer, SC	Electricity avg. kWh USA	IDEMAT 2001

4_WORKSURFACE RECTANGULAR	Tenoner, SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.1 Headset Drawer	CNC router (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.1 Headset Drawer	Finishing (finishing line), SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.1 Headset Drawer	Hand tool, electric	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.1 Headset Drawer	Hot-laminating press (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.1 Headset Drawer	Sanding, SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.1 Headset Drawer	Splicer, SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.1 Headset Drawer	Table saw, SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.1 Headset Drawer	Table saw, SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.1 Headset Drawer	Tenoner, SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.1 Headset Drawer	Tenoner, SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.1 Headset Drawer	Tenoner, SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.1 Headset Drawer	Tenoner, SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.4 Support WKSF, End	CNC router (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.4 Support WKSF, End	CNC router (wood), SC	Electricity avg. kWh USA	IDEMAT 2001

15_FILE PEDASTEL / 15.4 Support WKSF, End	Cut and edgeband, SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.4 Support WKSF, End	Dowel inserter, SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.4 Support WKSF, End	Finishing (finishing line), SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.4 Support WKSF, End	Hand tool, electric	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.4 Support WKSF, End	Hot-laminating press (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.4 Support WKSF, End	Sanding, SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.4 Support WKSF, End	Splicer, SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.4 Support WKSF, End	Tenoner, SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.5 Panel Knee	CNC router (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.5 Panel Knee	CNC router (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.5 Panel Knee	Cut and edgeband, SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.5 Panel Knee	Dowel inserter, SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.5 Panel Knee	Finishing (finishing line), SC	Electricity avg. kWh USA	IDEMAT 2001

15_FILE PEDASTEL / 15.5 Panel Knee	Hand tool, electric	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.5 Panel Knee	Hot-laminating press (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.5 Panel Knee	Sanding, SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.5 Panel Knee	Splicer, SC	Electricity avg. kWh USA	IDEMAT 2001
15_FILE PEDASTEL / 15.5 Panel Knee	Tenoner, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.1 Headset Drawer	CNC router (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.1 Headset Drawer	Finishing (finishing line), SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.1 Headset Drawer	Hand tool, electric	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.1 Headset Drawer	Hot-laminating press (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.1 Headset Drawer	Sanding, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.1 Headset Drawer	Splicer, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.1 Headset Drawer	Table saw, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.1 Headset Drawer	Table saw, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.1 Headset Drawer	Tenoner, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.1 Headset Drawer	Tenoner, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.1	Tenoner, SC	Electricity avg. kWh USA	IDEMAT 2001

Headset Drawer			
17_FILE PEDASTEL / 17.1 Headset Drawer	Tenoner, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.2 FileBack	Cut and edgeband, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.2 FileBack	Finishing (finishing line), SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.2 FileBack	Hand tool, electric	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.2 FileBack	Hot-laminating press (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.2 FileBack	Sanding, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.2 FileBack	Splicer, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.3 Support WKSF, End	Dowel inserter, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.3 Support WKSF, End	Finishing (finishing line), SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.3 Support WKSF, End	Hand tool, electric	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.3 Support WKSF, End	Hot-laminating press (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.3 Support WKSF, End	Sanding, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.3 Support WKSF, End	Splicer, SC	Electricity avg. kWh USA	IDEMAT 2001

17_FILE PEDASTEL / 17.3 Support WKSF, End	Table saw, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.3 Support WKSF, End	Table saw, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.3 Support WKSF, End	Table saw, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.3 Support WKSF, End	Tenoner, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.3 Support WKSF, End	Tenoner, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.4 Support WKSF, End	CNC router (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.4 Support WKSF, End	CNC router (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.4 Support WKSF, End	Cut and edgeband, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.4 Support WKSF, End	Dowel inserter, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.4 Support WKSF, End	Finishing (finishing line), SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.4 Support WKSF, End	Hand tool, electric	Electricity avg. kWh USA	IDEMAT 2001

17_FILE PEDASTEL / 17.4 Support WKSF, End	Hot-laminating press (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.4 Support WKSF, End	Sanding, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.4 Support WKSF, End	Splicer, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.4 Support WKSF, End	Tenoner, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.5 Panel Knee	CNC router (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.5 Panel Knee	CNC router (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.5 Panel Knee	Cut and edgeband, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.5 Panel Knee	Dowel inserter, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.5 Panel Knee	Finishing (finishing line), SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.5 Panel Knee	Hand tool, electric	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.5 Panel Knee	Hot-laminating press (wood), SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.5 Panel Knee	Sanding, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.5 Panel Knee	Splicer, SC	Electricity avg. kWh USA	IDEMAT 2001
17_FILE PEDASTEL / 17.5 Panel Knee	Tenoner, SC	Electricity avg. kWh USA	IDEMAT 2001

Slim Chair: Steelcase and Generic Processes by Component

Component	Steelcase Processes	Generic Processes	Generic Data Source
1_BASE_CASTERS _CYL, 1.1.1_Body 20mm Neck	Cast work, non-ferro, US	Electricity avg. kWh USA	IDEMAT 2001
1_BASE_CASTERS _CYL, 1.1.2 CasterWheels	Injection moulding, US	Injection Moulding I	IDEMAT 2001
1_BASE_CASTERS _CYL, 1.1.3_Pintle	Cold transforming steel, US	Rolling Steel I	IDEMAT 2001
1_BASE_CASTERS _CYL, 1.3_ Pneumatic Cylinder	Machining steel, US	Electricity avg. kWh USA	IDEMAT 2001
2_CHAIR CONTROL ARM STRAPS, 2.1.5_PneuLever	Cold transforming steel, US	Rolling Steel I	IDEMAT 2001
2_CHAIR CONTROL ARM STRAPS, 2.1.8_Torque AdjKnob	Injection moulding, US	Injection Moulding I	IDEMAT 2001
2_CHAIR CONTROL ARM STRAPS, 2.1.11_Back LockLever	Cold transforming steel, US	Rolling Steel I	IDEMAT 2001
2_CHAIR CONTROL ARM STRAPS, 2.1.12_BackLock	Injection moulding, US	Injection Moulding I	IDEMAT 2001
2_CHAIR CONTROL ARM STRAPS, 2.2.1_ArmStrap Front	Mech. Press, SC avg.	Electricity avg. kWh USA	IDEMAT 2001
2_CHAIR CONTROL ARM STRAPS, 2.3.1_SupportPlate RearArmStrap	Cutting steel laser, US	Electricity avg. kWh USA	IDEMAT 2001

2_CHAIR CONTROL ARM STRAPS, 2.3.2.4_Strap Arm Type2	Mech. Press, SC avg.	Electricity avg. kWh USA	IDEMAT 2001
2_CHAIR CONTROL ARM STRAPS, 3.1.1_Housing Control Chair	Mech. Press, SC avg.	Electricity avg. kWh USA	IDEMAT 2001
2_CHAIR CONTROL ARM STRAPS, 3.1.2_Support Bushing	Mech. Press, SC avg.	Electricity avg. kWh USA	IDEMAT 2001
2_CHAIR CONTROL ARM STRAPS, 3.1.3_Bushing HousingTapered	Mech. Press, SC avg.	Electricity avg. kWh USA	IDEMAT 2001
2_CHAIR CONTROL ARM STRAPS, 3.2.1_Support Upright	Mech. Press, SC avg.	Electricity avg. kWh USA	IDEMAT 2001
2_CHAIR CONTROL ARM STRAPS, 3.2.2_Support PivotSynchro	Mech. Press, SC avg.	Electricity avg. kWh USA	IDEMAT 2001
2_CHAIR CONTROL ARM STRAPS, 3.4_Tube Axle	Machining steel, US	Electricity avg. kWh USA	IDEMAT 2001
2_CHAIR CONTROL ARM STRAPS, 3.5_Spring Torsion LeftHand	Cold transforming steel, US	Rolling Steel I	IDEMAT 2001
2_CHAIR CONTROL ARM STRAPS, 3.6_Spring Torsion RightHand	Cold transforming steel, US	Rolling Steel I	IDEMAT 2001

2_CHAIR CONTROL ARM STRAPS, 3.8_Shaft Adjustment Tension Painted	Machining steel, US	Electricity avg. kWh USA	IDEMAT 2001
2_CHAIR CONTROL ARM STRAPS, 3.10_Plate Pivot Tension	Mech. Press, SC avg.	Electricity avg. kWh USA	IDEMAT 2001
6_BACK MECHANISM, 6.1.1.2_Tube BackMounting	Cutting steel laser, US	Electricity avg. kWh USA	IDEMAT 2001
6_BACK MECHANISM, 6.1.1.3_Tube CrossStretcher	Cold transforming steel, US	Rolling Steel I	IDEMAT 2001
6_BACK MECHANISM, 6.1.2.3_Cross Member Middle	Cold transforming steel, US	Rolling Steel I	IDEMAT 2001
6_BACK MECHANISM, 6.1.2.4_Cross Member Lower	Cold transforming steel, US	Rolling Steel I	IDEMAT 2001
6_BACK MECHANISM, 6.1.3.1_Cross Member Upper	Cold transforming steel, US	Rolling Steel I	IDEMAT 2001
6_BACK MECHANISM, 6.1.3.3_BackWire	Cold transforming steel, US	Rolling Steel I	IDEMAT 2001
6_BACK MECHANISM, 6.1.3.7_Link Upper Outer	Cutting steel laser, US	Electricity avg. kWh USA	IDEMAT 2001
6_BACK MECHANISM, 6.1.7_Rivet Main	Cold transforming steel, US	Rolling Steel I	IDEMAT 2001
6_BACK MECHANISM, 6.1.9_Spring	Cold transforming steel, US	Rolling Steel I	IDEMAT 2001
8_CHAIR CONTROL ARM STRAPS, 8.5.2_Guide Belt	Injection moulding, US	Injection Moulding I	IDEMAT 2001

H. Case Studies: Individual Process Comparisons

Airtouch Individual Process Results **Generic Data** **Steelcase Data**

Machining vs. Drilling Steel	Machining steel, US	Drilling steel, US
ERC	100%	59%
GWP	97%	100%
AP	100%	25%
CP	100%	36%
SW	100%	4%
TMC	100%	75%

Hand Tool vs. Electricity	Electricity	Hand Tool
ERC	100%	7%
GWP	100%	7%
AP	100%	7%
CP	100%	7%
SW	100%	7%
TMC	100%	7%

Welding Variations	Generic Weld	SC Weld
ERC	54%	100%
GWP	100%	46%
AP	5%	100%
CP	1%	100%
SW	60%	100%
TMC	100%	4%

Electricity vs. Linear Drive	Electricity	Linear Drive
ERC	100%	7%
GWP	100%	7%
AP	100%	7%
CP	100%	7%
SW	100%	7%
TMC	100%	7%

Electricity vs. Hand Tool, Pneumatic	Electricity	Hand Tool, Pneumatic
ERC	100%	93%
GWP	100%	93%
AP	100%	93%
CP	100%	93%
SW	100%	93%
TMC	100%	93%

Garland Individual Process Results **Generic Data** **Steelcase Data**

CNC vs. Elec	Machining steel, US	Drilling steel, US
ERC	73%	100%
GWP	73%	100%
AP	73%	100%
CP	73%	100%
SW	73%	100%
TMC	73%	100%

Cut/Edgeband vs. Elec	Machining steel, US	Drilling steel, US
ERC	100%	100%
GWP	100%	100%
AP	100%	100%
CP	100%	100%
SW	100%	100%
TMC	100%	100%

Dowel vs. Elec	Electricity	Hand Tool
ERC	100%	100%
GWP	100%	100%
AP	100%	100%
CP	100%	100%
SW	100%	100%
TMC	100%	100%

Finishing vs. Elec	Electricity	Hand Tool
ERC	100%	100%
GWP	100%	100%
AP	100%	100%
CP	100%	100%
SW	100%	100%
TMC	100%	100%

Hand Tool vs. Elec	**Generic Weld**	**SC Weld**
ERC	100%	100%
GWP	100%	100%
AP	100%	100%
CP	100%	100%
SW	100%	100%
TMC	100%	100%

Hot-Laminating vs. Elec	**Generic Weld**	**SC Weld**
ERC	87%	100%
GWP	87%	100%
AP	87%	100%
CP	87%	100%
SW	87%	100%
TMC	87%	100%

Sanding vs. Elec	**Generic Processes**	**SC Processes**
ERC	100%	100%
GWP	100%	100%
AP	100%	100%
CP	100%	100%
SW	100%	100%
TMC	100%	100%

Bander vs. Elec	**Electricity**	**Linear Drive**
ERC	100%	100%
GWP	100%	100%
AP	100%	100%
CP	100%	100%
SW	100%	100%
TMC	100%	100%

Splicer vs. Elec	**Electricity**	**Linear Drive**
ERC	100%	100%
GWP	100%	100%
AP	100%	100%
CP	100%	100%
SW	100%	100%
TMC	100%	100%

Table Saw vs. Elec	Electricity	Hand Tool, Pneumatic
ERC	100%	100%
GWP	100%	100%
AP	100%	100%
CP	100%	100%
SW	100%	100%
TMC	100%	100%

Tenoner vs. Elec	Electricity	Hand Tool, Pneumatic
ERC	100%	100%
GWP	100%	100%
AP	100%	100%
CP	100%	100%
SW	100%	100%
TMC	100%	100%

Slim Chair Individual Process Results Generic Data Steelcase Data

Zinc Cast vs. Elec	Electricity avg. kWh USA	Cast work, non-ferro, US
ERC	54%	100%
GWP	51%	100%
AP	46%	100%
CP	51%	100%
SW	31%	100%
TMC	49%	100%

Cold Transf vs. Cold Roll	Sheet Rolling Steel/RER U	Cold transforming steel, US
ERC	0%	100%
GWP	0%	100%
AP	0%	100%
CP	0%	100%
SW	100%	27%
TMC	78%	100%

Inject M vs. Inject M Generic	Injection Moulding/RER U	Injection moulding, US
ERC	0%	100%
GWP	0%	100%
AP	0%	100%
CP	0%	100%
SW	77%	100%
TMC	100%	3%

Machining vs. Elec	Electricity avg. kWh USA	Machining steel, US
ERC	100%	100%
GWP	100%	100%
AP	100%	100%
CP	100%	100%
SW	1%	100%
TMC	100%	100%

Mech Press vs. Elec	Electricity avg. kWh USA	Mech. Press, SC avg.
ERC	67%	100%
GWP	67%	100%
AP	67%	100%
CP	67%	100%
SW	67%	100%
TMC	67%	100%

Cutting Steel vs. Elec	Electricity avg. kWh USA	Cutting steel laser, US
ERC	100%	100%
GWP	100%	100%
AP	100%	100%
CP	100%	100%
SW	20%	100%
TMC	71%	100%

I. Case Studies: Process Comparisons in Product Profiles

Airtouch Component/Product Results **Generic Data** **Steelcase Data**

In Base Table: Machining vs. Drilling Steel	**Machining steel, US**	**Drilling steel, US**
ERC	100%	97%
GWP	100%	100%
AP	100%	93%
CP	100%	95%
SW	100%	45%
TMC	100%	98%

In Base Table: Hand Tool vs. Electricity	**Electricity**	**Hand Tool**
ERC	100%	99%
GWP	100%	99%
AP	100%	98%
CP	100%	98%
SW	100%	100%
TMC	100%	100%

In Base Table: Welding Variations	**Generic Weld**	**SC Weld**
ERC	98%	100%
GWP	100%	97%
AP	94%	100%
CP	95%	100%
SW	100%	100%
TMC	100%	93%

Full Base Table	**Generic Processes**	**SC Processes**
ERC	100%	99%
GWP	100%	97%
AP	100%	98%
CP	100%	99%
SW	100%	45%
TMC	100%	98%

In Column: Electricity vs. Linear Drive	Electricity	Linear Drive
ERC	100%	94%
GWP	100%	91%
AP	100%	97%
CP	100%	98%
SW	100%	87%
TMC	100%	76%

In Column: Electricity vs. Hand Tool, Pneumatic	Electricity	Hand Tool, Pneumatic
ERC	100%	94%
GWP	100%	91%
AP	100%	97%
CP	100%	98%
SW	100%	87%
TMC	100%	100%

Full Column	Generic Processes	SC Processes
ERC	100%	94%
GWP	100%	91%
AP	100%	97%
CP	100%	97%
SW	100%	87%
TMC	100%	76%

Full Airtouch	Generic Processes	SC Processes
ERC	100%	95%
GWP	100%	93%
AP	100%	98%
CP	100%	98%
SW	100%	72%
TMC	100%	76%

Garland Component/Product Results **Generic Data** **Steelcase Data**

Worksurface Rectangular	**Generic Processes**	**SC Processes**
ERC	97%	100%
GWP	96%	100%
AP	97%	100%
CP	97%	100%
SW	97%	100%
TMC	98%	100%

File Ped 15 - Headset Drawer	**Generic Processes**	**SC Processes**
ERC	94%	100%
GWP	94%	100%
AP	95%	100%
CP	94%	100%
SW	95%	100%
TMC	96%	100%

File Ped 15 - Support WKSF	**Generic Processes**	**SC Processes**
ERC	95%	100%
GWP	95%	100%
AP	96%	100%
CP	95%	100%
SW	97%	100%
TMC	97%	100%

File Ped 15 - Panel Knee	**Generic Processes**	**SC Processes**
ERC	96%	100%
GWP	95%	100%
AP	96%	100%
CP	96%	100%
SW	97%	100%
TMC	98%	100%

File Ped 15 - Full	**Generic Processes**	**SC Processes**
ERC	97%	100%
GWP	98%	100%
AP	97%	100%
CP	97%	100%
SW	99%	100%
TMC	99%	100%

File Ped 17 - Headset Drawer	**Generic Processes**	**SC Processes**
ERC	95%	100%
GWP	94%	100%
AP	95%	100%
CP	95%	100%
SW	95%	100%
TMC	96%	100%

File Ped 17 - FileBack	**Generic Processes**	**SC Processes**
ERC	100%	100%
GWP	100%	100%
AP	100%	100%
CP	100%	100%
SW	100%	100%
TMC	100%	100%

File Ped 17 - Base Wood	**Generic Processes**	**SC Processes**
ERC	99%	100%
GWP	99%	100%
AP	99%	100%
CP	99%	100%
SW	99%	100%
TMC	99%	100%

File Ped 17 - Support WKSF	**Generic Processes**	**SC Processes**
ERC	95%	100%
GWP	95%	100%
AP	96%	100%
CP	95%	100%
SW	97%	100%
TMC	97%	100%

File Ped 17 - Panel Knee	**Generic Processes**	**SC Processes**
ERC	96%	100%
GWP	95%	100%
AP	96%	100%
CP	96%	100%
SW	97%	100%
TMC	98%	100%

File Ped 17 - Full	Generic Processes	SC Processes
ERC	97%	100%
GWP	98%	100%
AP	97%	100%
CP	97%	100%
SW	99%	100%
TMC	99%	100%

Full Garland	Generic Processes	SC Processes
ERC	97%	100%
GWP	98%	100%
AP	97%	100%
CP	97%	100%
SW	99%	100%
TMC	99%	100%

Slim Chair Component/Product Results Generic Data Steelcase Data

1.1.1	Generic Processes	SC Processes
ERC	83%	100%
GWP	81%	100%
AP	86%	100%
CP	87%	100%
SW	60%	100%
TMC	83%	100%

1.1.2	Generic Processes	SC Processes
ERC	78%	100%
GWP	92%	100%
AP	80%	100%
CP	68%	100%
SW	87%	100%
TMC	100%	87%

1.1.3	Generic Processes	SC Processes
ERC	86%	100%
GWP	88%	100%
AP	79%	100%
CP	78%	100%
SW	100%	81%
TMC	99%	100%

1.3	**Generic Processes**	**SC Processes**
ERC	100%	96%
GWP	100%	96%
AP	100%	94%
CP	100%	93%
SW	65%	100%
TMC	99%	100%

1 Base Casters Full	**Generic Processes**	**SC Processes**
ERC	94%	100%
GWP	95%	100%
AP	93%	100%
CP	94%	100%
SW	94%	100%
TMC	100%	86%

2.1.5	**Generic Processes**	**SC Processes**
ERC	81%	100%
GWP	82%	100%
AP	75%	100%
CP	72%	100%
SW	100%	34%
TMC	99%	100%

2.1.8	**Generic Processes**	**SC Processes**
ERC	78%	100%
GWP	92%	100%
AP	80%	100%
CP	68%	100%
SW	87%	100%
TMC	100%	80%

2.1.11	**Generic Processes**	**SC Processes**
ERC	81%	100%
GWP	82%	100%
AP	75%	100%
CP	72%	100%
SW	100%	34%
TMC	99%	100%

2.1.12	**Generic Processes**	**SC Processes**
ERC	76%	100%
GWP	90%	100%
AP	76%	100%
CP	65%	100%
SW	89%	100%
TMC	100%	92%

2.2.1	**Generic Processes**	**SC Processes**
ERC	100%	100%
GWP	100%	100%
AP	99%	100%
CP	99%	100%
SW	100%	100%
TMC	100%	100%

2.3.1	**Generic Processes**	**SC Processes**
ERC	100%	100%
GWP	100%	100%
AP	100%	100%
CP	100%	100%
SW	99%	100%
TMC	100%	100%

2.3.2.4	**Generic Processes**	**SC Processes**
ERC	100%	100%
GWP	100%	100%
AP	99%	100%
CP	99%	100%
SW	100%	100%
TMC	100%	100%

3.1.1	**Generic Processes**	**SC Processes**
ERC	100%	100%
GWP	100%	100%
AP	99%	100%
CP	99%	100%
SW	100%	100%
TMC	100%	100%

3.1.2	**Generic Processes**	**SC Processes**
ERC	99%	100%
GWP	99%	100%
AP	97%	100%
CP	98%	100%
SW	100%	100%
TMC	100%	100%

3.1.3	**Generic Processes**	**SC Processes**
ERC	95%	100%
GWP	97%	100%
AP	90%	100%
CP	93%	100%
SW	99%	100%
TMC	100%	100%

3.2.1	**Generic Processes**	**SC Processes**
ERC	100%	100%
GWP	100%	100%
AP	99%	100%
CP	100%	100%
SW	100%	100%
TMC	100%	100%

3.2.2	**Generic Processes**	**SC Processes**
ERC	93%	100%
GWP	96%	100%
AP	87%	100%
CP	90%	100%
SW	99%	100%
TMC	99%	100%

3.4	**Generic Processes**	**SC Processes**
ERC	100%	100%
GWP	100%	100%
AP	100%	100%
CP	100%	100%
SW	10%	100%
TMC	75%	100%

3.5	Generic Processes	SC Processes
ERC	81%	100%
GWP	82%	100%
AP	75%	100%
CP	72%	100%
SW	100%	34%
TMC	99%	100%

3.6	Generic Processes	SC Processes
ERC	81%	100%
GWP	82%	100%
AP	75%	100%
CP	72%	100%
SW	100%	34%
TMC	99%	100%

3.8	Generic Processes	SC Processes
ERC	100%	100%
GWP	100%	100%
AP	100%	100%
CP	100%	100%
SW	64%	100%
TMC	97%	100%

3.10	Generic Processes	SC Processes
ERC	98%	100%
GWP	99%	100%
AP	95%	100%
CP	96%	100%
SW	100%	100%
TMC	100%	100%

2 Chair Control Full	Generic Processes	SC Processes
ERC	98%	100%
GWP	99%	100%
AP	96%	100%
CP	97%	100%
SW	96%	100%
TMC	100%	98%

6.1.1.2	**Generic Processes**	**SC Processes**
ERC	100%	100%
GWP	100%	100%
AP	100%	100%
CP	100%	100%
SW	43%	100%
TMC	95%	100%

6.1.1.3	**Generic Processes**	**SC Processes**
ERC	76%	100%
GWP	83%	100%
AP	61%	100%
CP	65%	100%
SW	100%	72%
TMC	99%	100%

6.1.2.3	**Generic Processes**	**SC Processes**
ERC	81%	100%
GWP	82%	100%
AP	75%	100%
CP	72%	100%
SW	100%	34%
TMC	99%	100%

6.1.2.4	**Generic Processes**	**SC Processes**
ERC	81%	100%
GWP	82%	100%
AP	75%	100%
CP	72%	100%
SW	100%	34%
TMC	99%	100%

6.1.3.1	**Generic Processes**	**SC Processes**
ERC	81%	100%
GWP	82%	100%
AP	75%	100%
CP	72%	100%
SW	100%	34%
TMC	99%	100%

6.1.3.3	**Generic Processes**	**SC Processes**
ERC	81%	100%
GWP	82%	100%
AP	75%	100%
CP	72%	100%
SW	100%	34%
TMC	99%	100%

6.1.3.7	**Generic Processes**	**SC Processes**
ERC	100%	100%
GWP	100%	100%
AP	100%	100%
CP	100%	100%
SW	99%	100%
TMC	100%	100%

6.1.7	**Generic Processes**	**SC Processes**
ERC	86%	100%
GWP	88%	100%
AP	79%	100%
CP	78%	100%
SW	100%	81%
TMC	98%	100%

6.1.9	**Generic Processes**	**SC Processes**
ERC	81%	100%
GWP	82%	100%
AP	75%	100%
CP	72%	100%
SW	100%	34%
TMC	99%	100%

6 Back Mech Full	**Generic Processes**	**SC Processes**
ERC	97%	100%
GWP	98%	100%
AP	98%	100%
CP	98%	100%
SW	100%	97%
TMC	100%	100%

8.5.2	**Generic Processes**	**SC Processes**
ERC	78%	100%
GWP	92%	100%
AP	80%	100%
CP	68%	100%
SW	87%	100%
TMC	100%	80%

Slim Chair Full	**Generic Processes**	**SC Processes**
ERC	98%	100%
GWP	99%	100%
AP	98%	100%
CP	98%	100%
SW	98%	100%
TMC	100%	98%

J. Case Studies: Transport Profiles Included in Analysis

Airtouch: Steelcase and Standard Transport Models

Steelcase-Specific Transport

Transportation Mode	Source	% of Product	Distance
Trailer Diesel, FAL US	Franklin USA 98	80%	14.43
Trailer Diesel, FAL US	Franklin USA 98	20%	31.03

Standard Comparison - Average

Transportation Mode	Source	% of Product	Distance
Trailer Diesel, FAL US	Franklin USA 98	100%	17.75

Standard Comparison - Max

Transportation Mode	Source	% of Product	Distance
Trailer Diesel, FAL US	Franklin USA 98	100%	1000 *

*Assuming max distance within US

Garland: Steelcase and Standard Transport Models

Steelcase-Specific Transport

Transportation Mode	Source	% of Product	Distance
Trailer Diesel, FAL US	Franklin USA 98	35%	38.06
Trailer Diesel, FAL US	Franklin USA 98	7%	8.43
Trailer Diesel, FAL US	Franklin USA 98	6%	2.83
Trailer Diesel, FAL US	Franklin USA 98	6%	5.75
Trailer Diesel, FAL US	Franklin USA 98	5%	1.31
Trailer Diesel, FAL US	Franklin USA 98	5%	1.15
Trailer Diesel, FAL US	Franklin USA 98	5%	6.14
Trailer Diesel, FAL US	Franklin USA 98	35%	83.99

Standard Comparison - Average

Transportation Mode	Source	% of Product	Distance
Trailer Diesel, FAL US	Franklin USA 98	100%	44.2524

Standard Comparison - Max

Transportation Mode	Source	% of Product	Distance
Trailer Diesel, FAL US	Franklin USA 98	100%	1000 *

*Assuming max distance within US

Slim Chair: Steelcase and Standard Transport Models

Steelcase-Specific Transport

Transportation Mode	Source	% of Product	Distance
Trailer Diesel, FAL US	Franklin USA 98		21.6
Trailer Diesel, FAL US	Franklin USA 98	35%	7.32
Trailer Diesel, FAL US	Franklin USA 98	7%	0.84
Trailer Diesel, FAL US	Franklin USA 98	6%	0.89
Trailer Diesel, FAL US	Franklin USA 98	6%	0.73
Trailer Diesel, FAL US	Franklin USA 98	5%	1.45
Trailer Diesel, FAL US	Franklin USA 98	5%	1.19
Trailer Diesel, FAL US	Franklin USA 98	5%	1.45
Trailer Diesel, FAL US	Franklin USA 98	35%	23.03

Standard Comparison - Average

Transportation Mode	Source	% of Product	Distance
Trailer Diesel, FAL US	Franklin USA 98	100%	21.6
Trailer Diesel, FAL US	Franklin USA 98	100%	10.983

Standard Comparison - Max

Transportation Mode	Source	% of Product	Distance
Trailer Diesel, FAL US	Franklin USA 98	100%	1000 *

*Assuming max distance within US

K. Case Studies: Transportation Profile Comparisons

Airtouch Transportation Results — Standard Data — Steelcase Data

Average vs. Specific Transport	Average	Specific
ERC	99%	100%
GWP	99%	100%
AP	99%	100%
CP	99%	100%
SW	100%	100%
TMC	100%	100%

Max vs. Specific Transport	Max	Specific
ERC	100%	70%
GWP	100%	68%
AP	100%	67%
CP	100%	74%
SW	100%	99%
TMC	100%	96%

Garland Transportation Results — Standard Data — Steelcase Data

Average vs. Specific Transport	Average	Specific
ERC	96%	100%
GWP	95%	100%
AP	95%	100%
CP	95%	100%
SW	100%	100%
TMC	99%	100%

Max vs. Specific Transport	Max	Specific
ERC	100%	73%
GWP	100%	70%
AP	100%	71%
CP	100%	70%
SW	100%	99%
TMC	100%	90%

Slim Chair Transportation Results **Standard Data** **Steelcase Data**

Average vs. Specific Transport	**Average**	**Specific**
ERC	97%	100%
GWP	97%	100%
AP	97%	100%
CP	97%	100%
SW	100%	100%
TMC	100%	100%

Max vs. Specific Transport	**Max**	**Specific**
ERC	100%	49%
GWP	100%	52%
AP	100%	47%
CP	100%	46%
SW	100%	98%
TMC	100%	93%

L. Case Studies: Product Profiles Used in Stage-Based Analysis

Blank slots in each profile indicate components and inputs not yet included in the profile to reflect limited information available at earlier stages of development.

Airtouch, Phase 0

A. BASE TABLE			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total			60.0000
3.1_Plate-Curved	1.0000	10.0000	10.0000
3.2_Tube-Square	2.0000	10.0000	20.0000
3.3_Glide	4.0000	5.0000	20.0000
3.3_Leg-Tube	2.0000	5.0000	10.0000
B. COLUMN			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total			51.0000
2.1_Column-Worksurface	1	10	10.0000
2.2_Bracket-Mechanism	1		8
2.2.7_Guide	2	1	2.0000
2.2.12_Brake-Actuator	1		6
2.2.12.2_Brake-Actuator	4	1	4.0000

2.2.12.15_Handle	1	1	1.0000
2.2.12.16_Brake-Actuator	1	1	1.0000
2.4_Plate-Mounting	1	5	5.0000
2.5_Column-Worksurface	1	15	15.0000
2.9_Rail	8	1	8.0000
2.12_Plate-Mounting	1	5	5.0000
C. WORK SURFACE			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total			58.7600
1.1_Particleboard	1130	0.05	56.5000
1.2_Laminate	1130	0.001	1.1300
1.3_Sheet-Backup	1130	0.001	1.1300

Airtouch, Phase 1

A. BASE TABLE			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total			60.0000
3.1_Plate-Curved	1.0000	10.0000	10.0000
3.2_Tube-Square	2.0000	10.0000	20.0000
3.3_Glide	4.0000	5.0000	20.0000
3.3_Leg-Tube	2.0000	5.0000	10.0000
B. COLUMN			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total			51.0000
2.1_Column-Worksurface	1	10	10.0000
2.2_Bracket-Mechanism	1		8
2.2.7_Guide	2	1	2.0000
2.2.12_Brake-Actuator	1		6
2.2.12.2_Brake-Actuator	4	1	4.0000

2.2.12.15_Handle	1	1	1.0000
2.2.12.16_Brake-Actuator	1	1	1.0000
2.4_Plate-Mounting	1	5	5.0000
2.5_Column-Worksurface	1	15	15.0000
2.9_Rail	8	1	8.0000
2.12_Plate-Mounting	1	5	5.0000
C. WORK SURFACE			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total			58.7600
1.1_Particleboard	1130	0.05	56.5000
1.2_Laminate	1130	0.001	1.1300
1.3_Sheet-Backup	1130	0.001	1.1300

Airtouch, Phase 2

A. BASE TABLE			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total			51.2832
3.1_Plate-Curved	1.0000	8.9609	8.9609
3.2_Tube-Square	2.0000	6.9782	13.9563
3.3_Glide	4.0000	4.6130	18.4520
3.3_Leg-Tube	2.0000	4.6130	9.2260
3.4_Cap-End	4.0000	0.1720	0.6880
B. COLUMN			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total			48.3923
2.1_Column-Worksurface	1	8.871	8.8710
2.2_Bracket-Mechanism	1		11.7433284
2.2.1_Plate-Mounting	1	0.9776	0.9776
2.2.2_Pin-Pivot	1	0	0.0000
2.2.3_Cam	1	0.6493	0.6493
2.2.4_Ball-Bearing	2	0	0.0000
2.2.5_Spring-Compression	1	2.178493	2.1785
2.2.6_Screw-Tapping	4	0	0.0000
2.2.7_Guide	2	0.5745	1.1490
2.2.8_Bearing	8	0.028638	0.2291
2.2.9_Bracket	1	0.312	0.3120
2.2.10_Mount-Vibration	6	0	0.0000
2.2.11_Nut-Acorn	3	0.114	0.3420
2.2.12_Brake-Actuator	1		4.8615142
2.2.12.1_Nut-Special	1		0
2.2.12.1.1_Nut-Special	1	0	0.0000
2.2.12.1.2_Nut-Special	1	0	0.0000
2.2.12.2_Brake-Actuator	4	0.65106	2.6042
2.2.12.3_Spring-Extension	1	0	0.0000
2.2.12.4_Cap-Filler	1	0	0.0000
2.2.12.5_Housing-Connector	1	0	0.0000
2.2.12.6_Bearing-Thrust	2	0	0.0000
2.2.12.7_Housing-Connector	1	0	0.0000
2.2.12.8_Screw-Special	1	0.562292	0.5623
2.2.12.9_Grommet	1	0	0.0000
2.2.12.10_Plate-Mounting	1	0	0.0000
2.2.12.11_Spring-Compression	1	0	0.0000

2.2.12.12_Washer-Wave	2	0	0.0000
2.2.12.13_Bushing	2	0	0.0000
2.2.12.14_Plate-Mounting	1	0	0.0000
2.2.12.15_Handle	1	0.214426	0.2144
2.2.12.16_Brake-Actuator	1	0.283239	0.2832
2.2.12.17_CablePackage	1	0.153	0.1530
2.2.12.18_Washer-Special	1	0	0.0000
2.2.12.19_Pin-Spring	1	0	1.0443
2.2.13_Plate-Mounting	1	0.158963	0.1590
2.2.14_Clip	2	0	0.0000
2.2.15_Spacer	2	0	0.0000
2.2.16_Screw-Tapping	4	0	0.0000
2.2.17_Cable-Power	1	0.8853542	0.8854
2.3_Bearing	8		0.807128
2.3.1_Ball-Bearing	1	0.039	0.0390
2.3.2_Spacer	1	0	0.0000
2.3.3_Screw-Special	1	0.061891	0.0619
2.4_Plate-Mounting	1	5.8044396	5.8044
2.5_Column-Worksurface	1	14.362	14.3620
2.6_Retainer	1	0	0.0000
2.7_Retainer	1	0.141491	0.1415
2.8_Cap-Junction	1	0	0.0000
2.9_Rail	8	0.076	0.6080
2.10_Pad	2	0	0.0000
2.11_Pad	4	0	0.0000
2.12_Plate-Mounting	1	6.0548893	6.0549
2.18_Screw-Tapping	6	0	0.0000
C. WORK SURFACE			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total			37.2390
1.1_Particleboard	1130	0.0293	33.1090
1.2_Laminate	1130	0.00136	1.5368
1.3_Sheet-Backup	1130	0.00146	1.6498
1.4_Edge-Worksurface	40	0.002	0.0800
1.5_Edge-Worksurface	97	0.007	0.6790
1.6_Adhesive-HotMelt	0.0417	0	0.0000
1.7_Adhesive_PressureSensitive	0.3688	0.5	0.1844

Airtouch, Phase 3

A. BASE TABLE			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total			64.4834
3.1_Plate-Curved	1.0000	8.9609	8.9609
3.2_Tube-Square	2.0000	6.9782	13.9563
3.3_Glide	4.0000	4.6130	18.4520
3.3_Leg-Tube	2.0000	4.6130	9.2260
3.4_Cap-End	4.0000	0.1720	0.6880
Packaging plastic bag, US	0.4100	0.4100	0.1681
Packaging cardboard, US	3.6100	3.6100	13.0321
Drilling steel, US (hours)			
Hand tool, electric, SC (hours)			
Welding, MIG SC (hours)			
B. COLUMN			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total			50.9923
2.1_Column-Worksurface	1	8.871	8.8710
2.2_Bracket-Mechanism	1		11.7433284
2.2.1_Plate-Mounting	1	0.9776	0.9776
2.2.2_Pin-Pivot	1	0	0.0000
2.2.3_Cam	1	0.6493	0.6493
2.2.4_Ball-Bearing	2	0	0.0000
2.2.5_Spring-Compression	1	2.178493	2.1785
2.2.6_Screw-Tapping	4	0	0.0000
2.2.7_Guide	2	0.5745	1.1490
2.2.8_Bearing	8	0.028638	0.2291
2.2.9_Bracket	1	0.312	0.3120
2.2.10_Mount-Vibration	6	0	0.0000
2.2.11_Nut-Acorn	3	0.114	0.3420
2.2.12_Brake-Actuator	1		4.8615142
2.2.12.1_Nut-Special	1		0
2.2.12.1.1_Nut-Special	1	0	0.0000
2.2.12.1.2_Nut-Special	1	0	0.0000
2.2.12.2_Brake-Actuator	4	0.65106	2.6042
2.2.12.3_Spring-Extension	1	0	0.0000
2.2.12.4_Cap-Filler	1	0	0.0000
2.2.12.5_Housing-Connector	1	0	0.0000
2.2.12.6_Bearing-Thrust	2	0	0.0000
2.2.12.7_Housing-Connector	1	0	0.0000
2.2.12.8_Screw-Special	1	0.562292	0.5623
2.2.12.9_Grommet	1	0	0.0000
2.2.12.10_Plate-Mounting	1	0	0.0000
2.2.12.11_Spring-Compression	1	0	0.0000

2.2.12.12_Washer-Wave	2	0	0.0000
2.2.12.13_Bushing	2	0	0.0000
2.2.12.14_Plate-Mounting	1	0	0.0000
2.2.12.15_Handle	1	0.214426	0.2144
2.2.12.16_Brake-Actuator	1	0.283239	0.2832
2.2.12.17_CablePackage	1	0.153	0.1530
2.2.12.18_Washer-Special	1	0	0.0000
2.2.12.19_Pin-Spring	1	0	1.0443
2.2.13_Plate-Mounting	1	0.158963	0.1590
2.2.14_Clip	2	0	0.0000
2.2.15_Spacer	2	0	0.0000
2.2.16_Screw-Tapping	4	0	0.0000
2.2.17_Cable-Power	1	0.8853542	0.8854
2.2.18_Label-Warning	1	0	0.0000
2.3_Bearing	8		0.807128
2.3.1_Ball-Bearing	1	0.039	0.0390
2.3.2_Spacer	1	0	0.0000
2.3.3_Screw-Special	1	0.061891	0.0619
2.4_Plate-Mounting	1	5.8044396	5.8044
2.5_Column-Worksurface	1	14.362	14.3620
2.6_Retainer	1	0	0.0000
2.7_Retainer	1	0.141491	0.1415
2.8_Cap-Junction	1	0	0.0000
2.9_Rail	8	0.076	0.6080
2.10_Pad	2	0	0.0000
2.11_Pad	4	0	0.0000
2.12_Plate-Mounting	1	6.0548893	6.0549
2.13_AssemblyDirection	1	0	0.0000
2.14_Label-Patent	1	0	0.0000
2.15_Label-Caution	1	0	0.0000
2.16_Label-Warning	1	0	0.0000
2.17_Label-Notice	1	0	0.0000
2.18_Screw-Tapping	6	0	0.0000
Packaging stretch foil, US	1	0.25	0.2500
Packaging tension band/banding strip, US	1	0.35	0.3500
Packaging cardboard, US	1	2	2.0000
Linear drive system, SC (hours)			
Hand tool, pneumatic (hours)			
C. WORK SURFACE			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total			37.4529
1.1_Particleboard	1130	0.0293	33.1090
1.2_Laminate	1130	0.00136	1.5368
1.3_Sheet-Backup	1130	0.00146	1.6498
1.4_Edge-Worksurface	40	0.002	0.0800

1.5_Edge-Worksurface	97	0.007	0.6790
1.6_Adhesive-HotMelt	0.0417	0	0.0000
1.7_Adhesive_PressureSensitive	0.3688	0.5	0.1844
1.8_Label-Patent	1	0	0.0000
1.9_Label-Information	1		0
1.9.1_Label-Blank	1	0	0.0000
1.9.2_Ink	0.00035	0	0.0000
1.10_AssemblyDirection	1	0	0.0000
1.11_Adhesive-HotMelt	0.0417	0	0.0000
1.12_Adhesive-PressureSensitive	0.3688	0.58	0.2139
1.13_Label-Information	1		0
1.13.1_Label-Blank	1	0	0.0000
1.13.2_Ink	0.00014	0	0.0000
1.14_Adhesive-HotMelt	0.0417	0	0.0000

Airtouch, Phase 4 (Full Product Profile)

A. BASE TABLE			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total			64.4834
3.1_Plate-Curved	1.0000	8.9609	8.9609
3.2_Tube-Square	2.0000	6.9782	13.9563
3.3_Glide	4.0000	4.6130	18.4520
3.3_Leg-Tube	2.0000	4.6130	9.2260
3.4_Cap-End	4.0000	0.1720	0.6880
Packaging plastic bag, US	0.4100	0.4100	0.1681
Packaging cardboard, US	3.6100	3.6100	13.0321
Drilling steel, US (hours)			
Hand tool, electric, SC (hours)			
Welding, MIG SC (hours)			
B. COLUMN			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total			50.9923
2.1_Column-Worksurface	1	8.871	8.8710
2.2_Bracket-Mechanism	1		11.7433284
2.2.1_Plate-Mounting	1	0.9776	0.9776
2.2.2_Pin-Pivot	1	0	0.0000
2.2.3_Cam	1	0.6493	0.6493
2.2.4_Ball-Bearing	2	0	0.0000
2.2.5_Spring-Compression	1	2.178493	2.1785
2.2.6_Screw-Tapping	4	0	0.0000
2.2.7_Guide	2	0.5745	1.1490
2.2.8_Bearing	8	0.028638	0.2291
2.2.9_Bracket	1	0.312	0.3120
2.2.10_Mount-Vibration	6	0	0.0000

2.2.11_Nut-Acorn	3	0.114	0.3420
2.2.12_Brake-Actuator	1		4.8615142
2.2.12.1_Nut-Special	1		0
2.2.12.1.1_Nut-Special	1	0	0.0000
2.2.12.1.2_Nut-Special	1	0	0.0000
2.2.12.2_Brake-Actuator	4	0.65106	2.6042
2.2.12.3_Spring-Extension	1	0	0.0000
2.2.12.4_Cap-Filler	1	0	0.0000
2.2.12.5_Housing-Connector	1	0	0.0000
2.2.12.6_Bearing-Thrust	2	0	0.0000
2.2.12.7_Housing-Connector	1	0	0.0000
2.2.12.8_Screw-Special	1	0.562292	0.5623
2.2.12.9_Grommet	1	0	0.0000
2.2.12.10_Plate-Mounting	1	0	0.0000
2.2.12.11_Spring-Compression	1	0	0.0000
2.2.12.12_Washer-Wave	2	0	0.0000
2.2.12.13_Bushing	2	0	0.0000
2.2.12.14_Plate-Mounting	1	0	0.0000
2.2.12.15_Handle	1	0.214426	0.2144
2.2.12.16_Brake-Actuator	1	0.283239	0.2832
2.2.12.17_CablePackage	1	0.153	0.1530
2.2.12.18_Washer-Special	1	0	0.0000
2.2.12.19_Pin-Spring	1	0	1.0443
2.2.13_Plate-Mounting	1	0.158963	0.1590
2.2.14_Clip	2	0	0.0000
2.2.15_Spacer	2	0	0.0000
2.2.16_Screw-Tapping	4	0	0.0000
2.2.17_Cable-Power	1	0.8853542	0.8854
2.2.18_Label-Warning	1	0	0.0000
2.3_Bearing	8		0.807128
2.3.1_Ball-Bearing	1	0.039	0.0390
2.3.2_Spacer	1	0	0.0000
2.3.3_Screw-Special	1	0.061891	0.0619
2.4_Plate-Mounting	1	5.8044396	5.8044
2.5_Column-Worksurface	1	14.362	14.3620
2.6_Retainer	1	0	0.0000
2.7_Retainer	1	0.141491	0.1415
2.8_Cap-Junction	1	0	0.0000
2.9_Rail	8	0.076	0.6080
2.10_Pad	2	0	0.0000
2.11_Pad	4	0	0.0000
2.12_Plate-Mounting	1	6.0548893	6.0549
2.13_AssemblyDirection	1	0	0.0000
2.14_Label-Patent	1	0	0.0000
2.15_Label-Caution	1	0	0.0000
2.16_Label-Warning	1	0	0.0000
2.17_Label-Notice	1	0	0.0000
2.18_Screw-Tapping	6	0	0.0000

Packaging stretch foil, US	1	0.25	0.2500
Packaging tension band/banding strip, US	1	0.35	0.3500
Packaging cardboard, US	1	2	2.0000
Linear drive system, SC (hours)			
Hand tool, pneumatic (hours)			
C. WORK SURFACE			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total			37.4529
1.1_Particleboard	1130	0.0293	33.1090
1.2_Laminate	1130	0.00136	1.5368
1.3_Sheet-Backup	1130	0.00146	1.6498
1.4_Edge-Worksurface	40	0.002	0.0800
1.5_Edge-Worksurface	97	0.007	0.6790
1.6_Adhesive-HotMelt	0.0417	0	0.0000
1.7_Adhesive_PressureSensitive	0.3688	0.5	0.1844
1.8_Label-Patent	1	0	0.0000
1.9_Label-Information	1		0
1.9.1_Label-Blank	1	0	0.0000
1.9.2_Ink	0.00035	0	0.0000
1.10_AssemblyDirection	1	0	0.0000
1.11_Adhesive-HotMelt	0.0417	0	0.0000
1.12_Adhesive-PressureSensitive	0.3688	0.58	0.2139
1.13_Label-Information	1		0
1.13.1_Label-Blank	1	0	0.0000
1.13.2_Ink	0.00014	0	0.0000
1.14_Adhesive-HotMelt	0.0417	0	0.0000

Garland, Phase 0

1_PANEL BACK			
Sub-Assemblies	# Units	Unit Weight (lbs)	Total Weight
Total	1.0000		0.0000
4_WORKSURFACE RECTANGULAR			
Sub-Assemblies	# Units	Unit Weight (lbs)	Total Weight
Total	1.0000		75.0000
4.1_Nosing	2.0000	2.0000	4.0000
Cherry	1	2	2.0000
Particleboard, US	1.0000	73.0800	70.0000
Cherry	1.0000	1.0000	1.0000

15_FILE PEDASTAL			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		59.2500
15.1_Headset Drawer	1		6.2500
Particleboard, US	1.0000	6.0000	6.0000
Cherry	1.0000	0.2500	0.2500
15.2_FileBack	1		6.2500
Particleboard, US	1.0000	6.0000	6.0000
Cherry	1.0000	0.2500	0.2500
15.3_Base Wood	1		1.7500
Particleboard, US	1.0000	1.5000	1.5000
Cherry	1.0000	0.2500	0.2500
15.4_Support WKSF,End	1		14.2500
Particleboard, US	1.0000	14.0000	14.0000
Cherry	1.0000	0.2500	0.2500

15.5_Panel Knee	1		15.7500
Particleboard, US	1.0000	15.5000	15.5000
Cherry	1.0000	0.2500	0.2500

15.26_Drawer File	2		15.0000
15.26.4_Purchased Plywood Drawer	1.0000	0.0000	7.5000
PNW Softwood Plywood	1.0000	7.5000	7.5000
17_FILE PEDASTEL			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		62.5000
17.1_Headset Drawer	1		5.7500
Particleboard, US	1.0000	5.5000	5.5000
Cherry	1.0000	0.2500	0.2500
17.2_FileBack	1		6.2500
Particleboard, US	1.0000	6.0000	6.0000
Cherry	1.0000	0.2500	0.2500
17.3_Base Wood	1		1.7500
Particleboard, US	1.0000	1.5000	1.5000

Cherry	1.0000	0.2500	0.2500
17.4_Support WKSF,End	1		14.5000
Particleboard, US	1.0000	14.0000	14.0000
Cherry	1.0000	0.5000	0.5000
17.5_Panel Knee	1		16.0000
Particleboard, US	1.0000	15.5000	15.5000
Cherry	1.0000	0.5000	0.5000

17.27_Drawer Box	2		11.0000
17.27.4_Purchased Plywood Drawer	1.0000		5.5000
PNW Softwood Plywood	1.0000	5.5000	5.5000
17.28_Drawer File	1		7.2500
17.28.4_Purchased Plywood Drawer	1.0000	0.0000	7.2500
PNW Softwood Plywood	1.0000	7.2500	7.2500

1_PANEL BACK			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	1.0000		0.0000
4_WORKSURFACE RECTANGULAR			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	1.0000		75.0000
4.1_Nosing	2.0000	2.0000	4.0000
Cherry Wood (final)	1	2	2.0000
Particleboard to Grand Rapids	1.0000	73.0800	70.0000
Cherry Veneer (final)	1.0000	1.0000	1.0000

15_FILE PEDASTAL			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		74.7500
15.1_Headset Drawer	1		6.2500
Particleboard to Grand Rapids	1.0000	6.0000	6.0000
Cherry Veneer (final)	1.0000	0.2500	0.2500
15.2_FileBack	1		6.2500
Particleboard to Grand Rapids	1.0000	6.0000	6.0000
Cherry Veneer (final)	1.0000	0.2500	0.2500
15.3_Base Wood	1		1.7500
Particleboard to Grand Rapids	1.0000	1.5000	1.5000
Cherry Veneer (final)	1.0000	0.2500	0.2500
15.4_Support WKSF,End	1		14.2500
Particleboard to Grand Rapids	1.0000	14.0000	14.0000
Cherry Veneer (final)	1.0000	0.2500	0.2500

15.5_Panel Knee	1		15.7500
Particleboard to Grand Rapids	1.0000	15.5000	15.5000
Cherry Veneer (final)	1.0000	0.2500	0.2500
15.6_Angle	2		2.5000
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.2500	1.2500
15.7_Angle	2		1.0000
IISI, Hot-dip Galvanized Coil, BF Route	1.0000	0.5000	0.5000
15.24_Slide	2		6.0000
IISI, Finished Cold Rolled Coil, BF Route	1.0000	3.0000	3.0000

15.25_Slide	2		6.0000
IISI, Finished Cold Rolled Coil, BF Route	1.0000	3.0000	3.0000
15.26_Drawer File	2		15.0000
15.26.4_Purchased Plywood Drawer	1.0000	0.0000	7.5000
PNW Softwood Plywood	1.0000	7.5000	7.5000
17_FILE PEDASTEL			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		76.0000
17.1_Headset Drawer	1		5.7500
Particleboard to Grand Rapids	1.0000	5.5000	5.5000
Cherry Veneer (final)	1.0000	0.2500	0.2500
17.2_FileBack	1		6.2500
Particleboard to Grand Rapids	1.0000	6.0000	6.0000
Cherry Veneer (final)	1.0000	0.2500	0.2500

17.3_Base Wood	1		1.7500
Particleboard to Grand Rapids	1.0000	1.5000	1.5000
Cherry Veneer (final)	1.0000	0.2500	0.2500
17.4_Support WKSF,End	1		14.5000
Particleboard to Grand Rapids	1.0000	14.0000	14.0000
Cherry Veneer (final)	1.0000	0.5000	0.5000
17.5_Panel Knee	1		16.0000
Particleboard to Grand Rapids	1.0000	15.5000	15.5000
Cherry Veneer (final)	1.0000	0.5000	0.5000
17.6_Angle	2		2.5000
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.2500	1.2500
17.7_Angle	2		1.0000
IISI, Hot-dip Galvanized Coil, BF Route	1.0000	0.5000	0.5000

17.24_Slide	1		3.0000
IISI, Finished Cold Rolled Coil, BF Route	1.0000	3.0000	3.0000
17.25_Slide	1		3.0000
IISI, Finished Cold Rolled Coil, BF Route	1.0000	3.0000	3.0000
17.26_Guide Drawer Track	4		4.0000
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.0000	1.0000
17.27_Drawer Box	2		11.0000
17.27.4_Purchased Plywood Drawer	1.0000		5.5000
PNW Softwood Plywood	1.0000	5.5000	5.5000
17.28_Drawer File	1		7.2500
17.28.4_Purchased Plywood Drawer	1.0000	0.0000	7.2500
PNW Softwood Plywood	1.0000	7.2500	7.2500

Garland, Phase 2

1_PANEL BACK			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	1.0000		0.0000
4_WORKSURFACE RECTANGULAR			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	1.0000		80.2400
4.1_Nosing	2.0000	2.1200	4.2400
Cherry Wood (final)	1	2.12	2.1200
Particleboard to Grand Rapids	1.0000	73.0800	73.0800
Cherry Veneer (final)	1.0000	0.8800	0.8800
Ethylene	1.0000	0.4300	0.4300
Backer Laminate	1.0000	1.6100	1.6100
10_ANGLE			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	1.0000		1.2850
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.2850	1.2850
11_SCREW TAPPING			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	10.0000		0.0000
12_SCREW TAPPING			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	12.0000		0.0000
13_CLEAT ATTACHMENT			
Sub-Assemblies	**# Units**	**Unit Weight**	**Total**

		(lbs)	Weight
Total	2.0000		0.8833
Poplar I, US	1.0000	0.4417	0.4417
14_PIN DOWEL			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	10.0000		1.0000
Red oak I, US	1.0000	0.1000	0.1000
15_FILE PEDASTAL			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		84.1799
15.1_Headset Drawer	1		6.1300
Particleboard to Grand Rapids	1.0000	5.8400	5.8400
Cherry Veneer (final)	1.0000	0.2300	0.2300
Ethylene	1.0000	0.0600	0.0600
15.2_FileBack	1		6.2700
Particleboard to Grand Rapids	1.0000	5.9700	5.9700
Cherry Veneer (final)	1.0000	0.2400	0.2400
Ethylene	1.0000	0.0600	0.0600
15.3_Base Wood	1		1.6000
Particleboard to Grand Rapids	1.0000	1.5300	1.5300
Cherry Veneer (final)	1.0000	0.0600	0.0600
Ethylene	1.0000	0.0100	0.0100
15.4_Support WKSF,End	1		14.9500
Particleboard to Grand Rapids	1.0000	14.2500	14.2500
Cherry Veneer (final)	1.0000	0.5600	0.5600
Ethylene	1.0000	0.1400	0.1400

15.5_Panel Knee	1		16.2900
Particleboard to Grand Rapids	1.0000	15.5300	15.5300
Cherry Veneer (final)	1.0000	0.6100	0.6100
Ethylene	1.0000	0.1500	0.1500
15.6_Angle	2		2.5160
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.2580	1.2580
15.7_Angle	2		0.9000
IISI, Hot-dip Galvanized Coil, BF Route	1.0000	0.4500	0.4500
15.8_Lock Catch	2		0.0000
15.9_Stretcher Rail	1		1.0000
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.0000	1.0000
15.10_Bracket	4		1.5280
IISI, Engineering Steel, EAF Route	1.0000	0.3820	0.3820
15.11_Hardware Package	2		0.3040
15.11.1_Handle	1.0000	0.1520	0.1520
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.1520	0.1520
15.11.2_Screw Machine	2.0000	0.0000	0.0000
15.12_Glide	4		0.0000
15.13_Cover Lock	1		0.0000
15.14_Bumper	4		0.2000
Polyurethane Rigid Foam	1.0000	0.0500	0.0500
15.15_Screw Tapping	8		0.0000
15.16_File Hanger	4		0.1800
PVC Pipe Extrusion	1.0000	0.0450	0.0450
15.17_Screw Tapping	2		0.0000
15.18_Screw Tapping	16		1.6000
Screw, self-tapping	1.0000	0.1000	0.1000
15.19_Screw Tapping	60		0.6000
Screw, self-tapping	1.0000	0.0100	0.0100
15.20_Lock Housing	1		0.0000
15.21_Lock Plug	1		0.0000
15.22_FileHanger	4		0.0000
15.23_Lock Bar	1		0.4859
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.4859	0.4859
15.24_Slide	2		5.9600

IISI, Finished Cold Rolled Coil, BF Route	1.0000	2.9800	2.9800
15.25_Slide	2		5.9600
IISI, Finished Cold Rolled Coil, BF Route	1.0000	2.9800	2.9800
15.26_Drawer File	2		16.8860
15.26.1_Guide Drawer Track	1.0000	0.0000	0.2100
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2100	0.2100
15.26.2_Guide Drawer Track	1.0000	0.0000	0.2100
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2100	0.2100
15.26.3_Screw Tapping	8.0000	0.0000	0.8000
Screw, self-tapping	1.0000	0.1000	0.1000
15.26.4_Purchased Plywood Drawer	1.0000	0.0000	7.2230
PNW Softwood Plywood	1.0000	7.2230	7.2230
15.27_Pin Dowel	4		0.4000
Red oak I, US	1.0000	0.1000	0.1000
15.28_Hardware Package	1		0.4200
15.28.1_Rail	2	0	0.4200
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.4970	0.4970
17_FILE PEDASTEL			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		90.1659
17.1_Headset Drawer	1		6.1300
Particleboard to Grand Rapids	1.0000	5.8400	5.8400
Cherry Veneer (final)	1.0000	0.2300	0.2300
Ethylene	1.0000	0.0600	0.0600
17.2_FileBack	1		6.2700
Particleboard to Grand Rapids	1.0000	5.9700	5.9700
Cherry Veneer (final)	1.0000	0.2400	0.2400
Ethylene	1.0000	0.0600	0.0600

17.3_Base Wood	1		1.6000
Particleboard to Grand Rapids	1.0000	1.5300	1.5300
Cherry Veneer (final)	1.0000	0.0600	0.0600
Ethylene	1.0000	0.0100	0.0100
17.4_Support WKSF,End	1		14.9500
Particleboard to Grand Rapids	1.0000	14.2500	14.2500
Cherry Veneer (final)	1.0000	0.5600	0.5600
Ethylene	1.0000	0.1400	0.1400
17.5_Panel Knee	1		16.2900
Particleboard to Grand Rapids	1.0000	15.5300	15.5300
Cherry Veneer (final)	1.0000	0.6100	0.6100
Ethylene	1.0000	0.1500	0.1500
17.6_Angle	2		2.5160
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.2580	1.2580
17.7_Angle	2		0.9000
IISI, Hot-dip Galvanized Coil, BF Route	1.0000	0.4500	0.4500
17.8_Lock Catch	3		0.0000

17.9_Stretcher Rail	1		0.9930
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.9930	0.9930
17.10_Hardware Package	3		0.1520
17.10.1_Handle	1.0000	0.0000	0.1520
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.1520	0.1520
17.10.2_Screw Machine	2.0000	0.0000	0.0000
17.11_Bracket	4		1.5280
IISI, Engineering Steel, EAF Route	1.0000	0.3820	0.3820
17.12_Glide	4		0.0000
17.13_Screw Tapping	60		0.6000
Screw, self-tapping	1.0000	0.0100	0.0100
17.14_Cover Lock	1		0.0000
17.15_Bumper	6		0.3000
Polyurethane Rigid Foam	1.0000	0.0500	0.0500
17.16_Screw Tapping	2		0.0000
17.17_File Hanger	2		0.0000
17.18_Screw Tapping	12		0.0000
17.19_Screw Tapping	20		2.0000
Screw, self-tapping	1.0000	0.1000	0.1000
17.20_Lock Housing	1		0.0000
17.21_Lock Plug	1		0.0000
17.22_File Hanger	2		0.0000
17.23_Lock Bar	1		0.4859
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.4859	0.4859
17.24_Slide	1		2.9800
IISI, Finished Cold Rolled Coil, BF Route	1.0000	2.9800	2.9800
17.25_Slide	1		2.9800
IISI, Finished Cold Rolled Coil, BF Route	1.0000	2.9800	2.9800
17.26_Guide Drawer Track	4		4.7600
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.1900	1.1900
17.27_Drawer Box	2		13.7440
17.27.1_Guide Drawer Track	1.0000	0.0000	0.2100
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2100	0.2100
17.27.2_Guide Drawer Track	1.0000	0.0000	0.2100
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2100	0.2100
17.27.3_Screw Tapping	8.0000	0.0000	0.8000
Screw, self-tapping	1.0000	0.1000	0.1000
17.27.4_Purchased Plywood Drawer	1.0000	0.0000	5.6520
PNW Softwood Plywood	1.0000	5.6520	5.6520
17.28_Drawer File	1		8.4430
17.28.1_Guide Drawer Track	1.0000	0.0000	0.2100
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2100	0.2100
17.28.2_Guide Drawer Track	1.0000	0.0000	0.2100
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2100	0.2100
17.28.3_Screw Tapping	8.0000	0.0000	0.8000
Screw, self-tapping	1.0000	0.1000	0.1000
17.28.4_Purchased Plywood Drawer	1.0000	0.0000	7.2230
PNW Softwood Plywood	1.0000	7.2230	7.2230

17.29_Pin Dowel	4		0.4000
Red oak I, US	1.0000	0.1000	0.1000
17.30_Hardware Package	1		1.3440
17.30.1_Tray	1	0	0.5300
Polystyrene (high impact) (HIPS)	1.0000	0.5300	0.5300
17.30.2_Support Accessory	3	0	0.0000
17.30.3_Rail	1	0	0.5000
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.5000	0.5000
17.30.4_Divider Drawer	2	0	0.3140
Red oak I, US	1.0000	0.1570	0.1570
17.31_Screw Metric	8		0.8000
IISI, Engineering Steel, EAF Route	1.0000	0.1000	0.1000

Garland, Phase 3

1_PANEL BACK			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	1.0000		0.0000
4_WORKSURFACE RECTANGULAR			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	1.0000		80.2400
4.1_Nosing	2.0000	2.1200	4.2400
Cherry Wood (final)	1	2.12	2.1200
Particleboard to Grand Rapids	1.0000	73.0800	73.0800
Cherry Veneer (final)	1.0000	0.8800	0.8800
Ethylene	1.0000	0.4300	0.4300
Backer Laminate	1.0000	1.6100	1.6100
Finishing (finishing line), SC			754.560
CNC router (wood), SC			666.684
CNC router (wood), SC			572.796
Hot-laminating press (wood), SC			546.192
Finishing (finishing line), SC			235.800
CNC router (wood), SC			178.596
Finishing (finishing line), SC			107.964
Hand tool, electric			75.600
Single edge bander, SC			72.360
Finishing (finishing line), SC			46.368
Splicer, SC			40.860
Hot-laminating press (wood), SC			29.520
Tenoner, SC			0.036
10_ANGLE			
Sub-Assemblies	**# Units**	**Unit Weight**	**Total**

		(lbs)	Weight
Total	1.0000		1.2850
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.2850	1.2850
11_SCREW TAPPING			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	10.0000		0.0000
12_SCREW TAPPING			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	12.0000		0.0000
13_CLEAT ATTACHMENT			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	2.0000		0.8833
Poplar I, US	1.0000	0.4417	0.4417
14_PIN DOWEL			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	10.0000		1.0000
Red oak I, US	1.0000	0.1000	0.1000
15_FILE PEDASTAL			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		84.1799
15.1_Headset Drawer	1		6.1300
Particleboard to Grand Rapids	1.0000	5.8400	5.8400
Cherry Veneer (final)	1.0000	0.2300	0.2300
Ethylene	1.0000	0.0600	0.0600
Hand tool, electric			394.056
CNC router (wood), SC			270.216
Sanding, SC			252.000
Tenoner, SC			168.768
Tenoner, SC			93.780
Tenoner, SC			71.316
Table saw, SC			28.800
Table saw, SC			28.800
Hot-laminating press (wood), SC			15.120
Finishing (finishing line), SC			9.252
Splicer, SC			7.920
Tenoner, SC			0.036
15.2_FileBack	1		6.2700
Particleboard to Grand Rapids	1.0000	5.9700	5.9700
Cherry Veneer (final)	1.0000	0.2400	0.2400

Ethylene	1.0000	0.0600	0.0600
15.3_Base Wood	1		1.6000
Particleboard to Grand Rapids	1.0000	1.5300	1.5300
Cherry Veneer (final)	1.0000	0.0600	0.0600
Ethylene	1.0000	0.0100	0.0100
15.4_Support WKSF,End	1		14.9500
Particleboard to Grand Rapids	1.0000	14.2500	14.2500
Cherry Veneer (final)	1.0000	0.5600	0.5600
Ethylene	1.0000	0.1400	0.1400
Hand tool, electric			288.0000
CNC router (wood), SC			267.3000
Sanding, SC			252.0000
Dowel inserter, SC			82.0080
CNC router (wood), SC			42.984
Cut and edgeband, SC			24.2280
Finishing (finishing line), SC			18.5400
Splicer, SC			17.2800
Hot-laminating press (wood), SC			15.1200
Tenoner, SC			0.036
15.5_Panel Knee	1		16.2900
Particleboard to Grand Rapids	1.0000	15.5300	15.5300
Cherry Veneer (final)	1.0000	0.6100	0.6100
Ethylene	1.0000	0.1500	0.1500
Hand tool, electric			288.0000
CNC router (wood), SC			267.3000
Sanding, SC			252.0000
Dowel inserter, SC			72.0000
CNC router (wood), SC			39.24
Cut and edgeband, SC			24.2280
Finishing (finishing line), SC			18.5400
Splicer, SC			17.2800
Hot-laminating press (wood), SC			15.1200
Tenoner, SC			0.036
15.6_Angle	2		2.5160
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.2580	1.2580
15.7_Angle	2		0.9000
IISI, Hot-dip Galvanized Coil, BF Route	1.0000	0.4500	0.4500
15.8_Lock Catch	2		0.0000
15.9_Stretcher Rail	1		1.0000
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.0000	1.0000
15.10_Bracket	4		1.5280
IISI, Engineering Steel, EAF Route	1.0000	0.3820	0.3820
15.11_Hardware Package	2		0.3040
15.11.1_Handle	1.0000	0.1520	0.1520
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.1520	0.1520
15.11.2_Screw Machine	2.0000	0.0000	0.0000
15.12_Glide	4		0.0000
15.13_Cover Lock	1		0.0000

15.14_Bumper	4		0.2000
Polyurethane Rigid Foam	1.0000	0.0500	0.0500
15.15_Screw Tapping	8		0.0000
15.16_File Hanger	4		0.1800
PVC Pipe Extrusion	1.0000	0.0450	0.0450
15.17_Screw Tapping	2		0.0000
15.18_Screw Tapping	16		1.6000
Screw, self-tapping	1.0000	0.1000	0.1000
15.19_Screw Tapping	60		0.6000
Screw, self-tapping	1.0000	0.0100	0.0100
15.20_Lock Housing	1		0.0000
15.21_Lock Plug	1		0.0000
15.22_FileHanger	4		0.0000
15.23_Lock Bar	1		0.4859
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.4859	0.4859
15.24_Slide	2		5.9600
IISI, Finished Cold Rolled Coil, BF Route	1.0000	2.9800	2.9800
15.25_Slide	2		5.9600
IISI, Finished Cold Rolled Coil, BF Route	1.0000	2.9800	2.9800
15.26_Drawer File	2		16.8860
15.26.1_Guide Drawer Track	1.0000	0.0000	0.2100
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2100	0.2100
15.26.2_Guide Drawer Track	1.0000	0.0000	0.2100
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2100	0.2100
15.26.3_Screw Tapping	8.0000	0.0000	0.8000
Screw, self-tapping	1.0000	0.1000	0.1000
15.26.4_Purchased Plywood Drawer	1.0000	0.0000	7.2230
PNW Softwood Plywood	1.0000	7.2230	7.2230
15.27_Pin Dowel	4		0.4000
Red oak I, US	1.0000	0.1000	0.1000
15.28_Hardware Package	1		0.4200
15.28.1_Rail	2	0	0.4200
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.4970	0.4970
17_FILE PEDASTEL			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		90.1659
17.1_Headset Drawer	1		6.1300
Particleboard to Grand Rapids	1.0000	5.8400	5.8400
Cherry Veneer (final)	1.0000	0.2300	0.2300
Ethylene	1.0000	0.0600	0.0600
Hand tool, electric			394.0560
CNC router (wood), SC			270.2160
Sanding, SC			252.0000
Tenoner, SC			243.7200
Tenoner, SC			93.78
Tenoner, SC			71.3160

Table saw, SC			28.8000
Table saw, SC			28.8000
Hot-laminating press (wood), SC			15.1200
Finishing (finishing line), SC			9.252
Splicer, SC			7.9200
Tenoner, SC			0.0360
17.2_FileBack	1		6.2700
Particleboard to Grand Rapids	1.0000	5.9700	5.9700
Cherry Veneer (final)	1.0000	0.2400	0.2400
Ethylene	1.0000	0.0600	0.0600
Sanding, SC			252.0000
Hand tool, electric			160.5600
Cut and edgeband, SC			24.2280
Hot-laminating press (wood), SC			15.1200
Finishing (finishing line), SC			9.252
Splicer, SC			7.6680
17.3_Base Wood	1		1.6000
Particleboard to Grand Rapids	1.0000	1.5300	1.5300
Cherry Veneer (final)	1.0000	0.0600	0.0600
Ethylene	1.0000	0.0100	0.0100
Hand tool, electric			288.0000
Table saw, SC			57.6000
Dowel inserter, SC			47.1600
Table saw, SC			36.3600
Table saw, SC			28.8
Tenoner, SC			23.6160
Hot-laminating press (wood), SC			15.1200
Finishing (finishing line), SC			9.2520
Sanding, SC			9.0000
Splicer, SC			4.176
Tenoner, SC			0.036
17.4_Support WKSF,End	1		14.9500
Particleboard to Grand Rapids	1.0000	14.2500	14.2500
Cherry Veneer (final)	1.0000	0.5600	0.5600
Ethylene	1.0000	0.1400	0.1400
Hand tool, electric			288.0000
CNC router (wood), SC			267.3000
Sanding, SC			252.0000
Dowel inserter, SC			82.0080
CNC router (wood), SC			42.984
Cut and edgeband, SC			24.2280
Finishing (finishing line), SC			18.5400
Splicer, SC			17.2800
Hot-laminating press (wood), SC			15.1200
Tenoner, SC			0.036
17.5_Panel Knee	1		16.2900
Particleboard to Grand Rapids	1.0000	15.5300	15.5300
Cherry Veneer (final)	1.0000	0.6100	0.6100

Ethylene	1.0000	0.1500	0.1500
Hand tool, electric			288.0000
CNC router (wood), SC			267.3000
Sanding, SC			252.0000
Dowel inserter, SC			72.0000
CNC router (wood), SC			39.24
Cut and edgeband, SC			24.2280
Finishing (finishing line), SC			18.5400
Splicer, SC			17.2800
Hot-laminating press (wood), SC			15.1200
Tenoner, SC			0.036
17.6_Angle	2		2.5160
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.2580	1.2580
17.7_Angle	2		0.9000
IISI, Hot-dip Galvanized Coil, BF Route	1.0000	0.4500	0.4500
17.8_Lock Catch	3		0.0000
17.9_Stretcher Rail	1		0.9930
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.9930	0.9930
17.10_Hardware Package	3		0.1520
17.10.1_Handle	1.0000	0.0000	0.1520
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.1520	0.1520
17.10.2_Screw Machine	2.0000	0.0000	0.0000
17.11_Bracket	4		1.5280
IISI, Engineering Steel, EAF Route	1.0000	0.3820	0.3820
17.12_Glide	4		0.0000
17.13_Screw Tapping	60		0.6000
Screw, self-tapping	1.0000	0.0100	0.0100
17.14_Cover Lock	1		0.0000
17.15_Bumper	6		0.3000
Polyurethane Rigid Foam	1.0000	0.0500	0.0500
17.16_Screw Tapping	2		0.0000
17.17_File Hanger	2		0.0000
17.18_Screw Tapping	12		0.0000
17.19_Screw Tapping	20		2.0000
Screw, self-tapping	1.0000	0.1000	0.1000
17.20_Lock Housing	1		0.0000
17.21_Lock Plug	1		0.0000
17.22_File Hanger	2		0.0000
17.23_Lock Bar	1		0.4859
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.4859	0.4859
17.24_Slide	1		2.9800
IISI, Finished Cold Rolled Coil, BF Route	1.0000	2.9800	2.9800
17.25_Slide	1		2.9800
IISI, Finished Cold Rolled Coil, BF Route	1.0000	2.9800	2.9800
17.26_Guide Drawer Track	4		4.7600
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.1900	1.1900
17.27_Drawer Box	2		13.7440
17.27.1_Guide Drawer Track	1.0000	0.0000	0.2100

IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2100	0.2100
17.27.2_Guide Drawer Track	1.0000	0.0000	0.2100
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2100	0.2100
17.27.3_Screw Tapping	8.0000	0.0000	0.8000
Screw, self-tapping	1.0000	0.1000	0.1000
17.27.4_Purchased Plywood Drawer	1.0000	0.0000	5.6520
PNW Softwood Plywood	1.0000	5.6520	5.6520
17.28_Drawer File	1		8.4430
17.28.1_Guide Drawer Track	1.0000	0.0000	0.2100
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2100	0.2100
17.28.2_Guide Drawer Track	1.0000	0.0000	0.2100
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2100	0.2100
17.28.3_Screw Tapping	8.0000	0.0000	0.8000
Screw, self-tapping	1.0000	0.1000	0.1000
17.28.4_Purchased Plywood Drawer	1.0000	0.0000	7.2230
PNW Softwood Plywood	1.0000	7.2230	7.2230
17.29_Pin Dowel	4		0.4000
Red oak I, US	1.0000	0.1000	0.1000
17.30_Hardware Package	1		1.3440
17.30.1_Tray	1	0	0.5300
Polystyrene (high impact) (HIPS)	1.0000	0.5300	0.5300
17.30.2_Support Accessory	3	0	0.0000
17.30.3_Rail	1	0	0.5000
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.5000	0.5000
17.30.4_Divider Drawer	2	0	0.3140
Red oak I, US	1.0000	0.1570	0.1570
17.31_Screw Metric	8		0.8000
IISI, Engineering Steel, EAF Route	1.0000	0.1000	0.1000
19_BOOKLET			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	1.0000		0.0000
20_GROMMET LOCATION			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	1.0000		0.0000
20.1_CablePackage	1.0000		0.0000
20.1.1_CablePackage	1		0.0000
20.1.2_Wireway	2		0.0000
21_GROMMET LOCATION			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	0.0000		0.0000
21.1_CablePackage	1.0000		0.0000
21.1.1_CablePackage	1		0.0000
21.1.2_Wireway	2		0.0000

PACKAGING WOOD, US			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total		12.8900	12.8900
PACKAGING CARDBOARD, US			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total		3.6560	3.6560
PACKAGING HONEYCOMB, US			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total		3.8400	3.8400
PACKAGING PAPER, US			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total		0.9960	0.9960
PACKAGING STRETCH FOIL, US			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total		0.8570	0.8570

Garland, Phase 4 (Full Product Profile)

1_PANEL BACK			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	1.0000		0.0000
4_WORKSURFACE RECTANGULAR			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	1.0000		80.2400
4.1_Nosing	2.0000	2.1200	4.2400
Cherry Wood (final)	1	2.12	2.1200
Particleboard to Grand Rapids	1.0000	73.0800	73.0800
Cherry Veneer (final)	1.0000	0.8800	0.8800
Ethylene	1.0000	0.4300	0.4300
Backer Laminate	1.0000	1.6100	1.6100
Finishing (finishing line), SC			754.560
CNC router (wood), SC			666.684
CNC router (wood), SC			572.796
Hot-laminating press (wood), SC			546.192

Finishing (finishing line), SC			235.800
CNC router (wood), SC			178.596
Finishing (finishing line), SC			107.964
Hand tool, electric			75.600
Single edge bander, SC			72.360
Finishing (finishing line), SC			46.368
Splicer, SC			40.860
Hot-laminating press (wood), SC			29.520
Tenoner, SC			0.036
10_ANGLE			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	1.0000		1.2850
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.2850	1.2850
11_SCREW TAPPING			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	10.0000		0.0000
12_SCREW TAPPING			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	12.0000		0.0000
13_CLEAT ATTACHMENT			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	2.0000		0.8833
Poplar I, US	1.0000	0.4417	0.4417
14_PIN DOWEL			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	10.0000		1.0000
Red oak I, US	1.0000	0.1000	0.1000
15_FILE PEDASTAL			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		84.1799
15.1_Headset Drawer	1		6.1300
Particleboard to Grand Rapids	1.0000	5.8400	5.8400
Cherry Veneer (final)	1.0000	0.2300	0.2300
Ethylene	1.0000	0.0600	0.0600
Hand tool, electric			394.056
CNC router (wood), SC			270.216
Sanding, SC			252.000

Tenoner, SC			168.768
Tenoner, SC			93.780
Tenoner, SC			71.316
Table saw, SC			28.800
Table saw, SC			28.800
Hot-laminating press (wood), SC			15.120
Finishing (finishing line), SC			9.252
Splicer, SC			7.920
Tenoner, SC			0.036
15.2_FileBack	1		6.2700
Particleboard to Grand Rapids	1.0000	5.9700	5.9700
Cherry Veneer (final)	1.0000	0.2400	0.2400
Ethylene	1.0000	0.0600	0.0600
15.3_Base Wood	1		1.6000
Particleboard to Grand Rapids	1.0000	1.5300	1.5300
Cherry Veneer (final)	1.0000	0.0600	0.0600
Ethylene	1.0000	0.0100	0.0100
15.4_Support WKSF,End	1		14.9500
Particleboard to Grand Rapids	1.0000	14.2500	14.2500
Cherry Veneer (final)	1.0000	0.5600	0.5600
Ethylene	1.0000	0.1400	0.1400
Hand tool, electric			288.0000
CNC router (wood), SC			267.3000
Sanding, SC			252.0000
Dowel inserter, SC			82.0080
CNC router (wood), SC			42.984
Cut and edgeband, SC			24.2280
Finishing (finishing line), SC			18.5400
Splicer, SC			17.2800
Hot-laminating press (wood), SC			15.1200
Tenoner, SC			0.036
15.5_Panel Knee	1		16.2900
Particleboard to Grand Rapids	1.0000	15.5300	15.5300
Cherry Veneer (final)	1.0000	0.6100	0.6100
Ethylene	1.0000	0.1500	0.1500
Hand tool, electric			288.0000
CNC router (wood), SC			267.3000
Sanding, SC			252.0000
Dowel inserter, SC			72.0000
CNC router (wood), SC			39.24
Cut and edgeband, SC			24.2280
Finishing (finishing line), SC			18.5400
Splicer, SC			17.2800
Hot-laminating press (wood), SC			15.1200
Tenoner, SC			0.036
15.6_Angle	2		2.5160
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.2580	1.2580
15.7_Angle	2		0.9000

IISI, Hot-dip Galvanized Coil, BF Route	1.0000	0.4500	0.4500
15.8_Lock Catch	2		0.0000
15.9_Stretcher Rail	1		1.0000
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.0000	1.0000
15.10_Bracket	4		1.5280
IISI, Engineering Steel, EAF Route	1.0000	0.3820	0.3820
15.11_Hardware Package	2		0.3040
15.11.1_Handle	1.0000	0.1520	0.1520
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.1520	0.1520
15.11.2_Screw Machine	2.0000	0.0000	0.0000
15.12_Glide	4		0.0000
15.13_Cover Lock	1		0.0000
15.14_Bumper	4		0.2000
Polyurethane Rigid Foam	1.0000	0.0500	0.0500
15.15_Screw Tapping	8		0.0000
15.16_File Hanger	4		0.1800
PVC Pipe Extrusion	1.0000	0.0450	0.0450
15.17_Screw Tapping	2		0.0000
15.18_Screw Tapping	16		1.6000
Screw, self-tapping	1.0000	0.1000	0.1000
15.19_Screw Tapping	60		0.6000
Screw, self-tapping	1.0000	0.0100	0.0100
15.20_Lock Housing	1		0.0000
15.21_Lock Plug	1		0.0000
15.22_FileHanger	4		0.0000
15.23_Lock Bar	1		0.4859
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.4859	0.4859
15.24_Slide	2		5.9600
IISI, Finished Cold Rolled Coil, BF Route	1.0000	2.9800	2.9800
15.25_Slide	2		5.9600
IISI, Finished Cold Rolled Coil, BF Route	1.0000	2.9800	2.9800
15.26_Drawer File	2		16.8860
15.26.1_Guide Drawer Track	1.0000	0.0000	0.2100
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2100	0.2100
15.26.2_Guide Drawer Track	1.0000	0.0000	0.2100
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2100	0.2100
15.26.3_Screw Tapping	8.0000	0.0000	0.8000
Screw, self-tapping	1.0000	0.1000	0.1000
15.26.4_Purchased Plywood Drawer	1.0000	0.0000	7.2230
PNW Softwood Plywood	1.0000	7.2230	7.2230
15.27_Pin Dowel	4		0.4000
Red oak I, US	1.0000	0.1000	0.1000
15.28_Hardware Package	1		0.4200
15.28.1_Rail	2	0	0.4200
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.4970	0.4970
17_FILE PEDASTEL			
Sub-Assemblies	**Units**	**Unit Weight**	**Total**

		(lbs)	**Weight**
Total	**1.0000**		90.1659
17.1_Headset Drawer	1		6.1300
Particleboard to Grand Rapids	1.0000	5.8400	5.8400
Cherry Veneer (final)	1.0000	0.2300	0.2300
Ethylene	1.0000	0.0600	0.0600
Hand tool, electric			394.0560
CNC router (wood), SC			270.2160
Sanding, SC			252.0000
Tenoner, SC			243.7200
Tenoner, SC			93.78
Tenoner, SC			71.3160
Table saw, SC			28.8000
Table saw, SC			28.8000
Hot-laminating press (wood), SC			15.1200
Finishing (finishing line), SC			9.252
Splicer, SC			7.9200
Tenoner, SC			0.0360
17.2_FileBack	1		6.2700
Particleboard to Grand Rapids	1.0000	5.9700	5.9700
Cherry Veneer (final)	1.0000	0.2400	0.2400
Ethylene	1.0000	0.0600	0.0600
Sanding, SC			252.0000
Hand tool, electric			160.5600
Cut and edgeband, SC			24.2280
Hot-laminating press (wood), SC			15.1200
Finishing (finishing line), SC			9.252
Splicer, SC			7.6680
17.3_Base Wood	1		1.6000
Particleboard to Grand Rapids	1.0000	1.5300	1.5300
Cherry Veneer (final)	1.0000	0.0600	0.0600
Ethylene	1.0000	0.0100	0.0100
Hand tool, electric			288.0000
Table saw, SC			57.6000
Dowel inserter, SC			47.1600
Table saw, SC			36.3600
Table saw, SC			28.8
Tenoner, SC			23.6160
Hot-laminating press (wood), SC			15.1200
Finishing (finishing line), SC			9.2520
Sanding, SC			9.0000
Splicer, SC			4.176
Tenoner, SC			0.036
17.4_Support WKSF,End	1		14.9500
Particleboard to Grand Rapids	1.0000	14.2500	14.2500
Cherry Veneer (final)	1.0000	0.5600	0.5600
Ethylene	1.0000	0.1400	0.1400
Hand tool, electric			288.0000

CNC router (wood), SC			267.3000
Sanding, SC			252.0000
Dowel inserter, SC			82.0080
CNC router (wood), SC			42.984
Cut and edgeband, SC			24.2280
Finishing (finishing line), SC			18.5400
Splicer, SC			17.2800
Hot-laminating press (wood), SC			15.1200
Tenoner, SC			0.036
17.5_Panel Knee	1		16.2900
Particleboard to Grand Rapids	1.0000	15.5300	15.5300
Cherry Veneer (final)	1.0000	0.6100	0.6100
Ethylene	1.0000	0.1500	0.1500
Hand tool, electric			288.0000
CNC router (wood), SC			267.3000
Sanding, SC			252.0000
Dowel inserter, SC			72.0000
CNC router (wood), SC			39.24
Cut and edgeband, SC			24.2280
Finishing (finishing line), SC			18.5400
Splicer, SC			17.2800
Hot-laminating press (wood), SC			15.1200
Tenoner, SC			0.036
17.6_Angle	2		2.5160
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.2580	1.2580
17.7_Angle	2		0.9000
IISI, Hot-dip Galvanized Coil, BF Route	1.0000	0.4500	0.4500
17.8_Lock Catch	3		0.0000
17.9_Stretcher Rail	1		0.9930
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.9930	0.9930
17.10_Hardware Package	3		0.1520
17.10.1_Handle	1.0000	0.0000	0.1520
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.1520	0.1520
17.10.2_Screw Machine	2.0000	0.0000	0.0000
17.11_Bracket	4		1.5280
IISI, Engineering Steel, EAF Route	1.0000	0.3820	0.3820
17.12_Glide	4		0.0000
17.13_Screw Tapping	60		0.6000
Screw, self-tapping	1.0000	0.0100	0.0100
17.14_Cover Lock	1		0.0000
17.15_Bumper	6		0.3000
Polyurethane Rigid Foam	1.0000	0.0500	0.0500
17.16_Screw Tapping	2		0.0000
17.17_File Hanger	2		0.0000
17.18_Screw Tapping	12		0.0000
17.19_Screw Tapping	20		2.0000
Screw, self-tapping	1.0000	0.1000	0.1000
17.20_Lock Housing	1		0.0000

17.21_Lock Plug	1		0.0000
17.22_File Hanger	2		0.0000
17.23_Lock Bar	1		0.4859
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.4859	0.4859
17.24_Slide	1		2.9800
IISI, Finished Cold Rolled Coil, BF Route	1.0000	2.9800	2.9800
17.25_Slide	1		2.9800
IISI, Finished Cold Rolled Coil, BF Route	1.0000	2.9800	2.9800
17.26_Guide Drawer Track	4		4.7600
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.1900	1.1900
17.27_Drawer Box	2		13.7440
17.27.1_Guide Drawer Track	1.0000	0.0000	0.2100
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2100	0.2100
17.27.2_Guide Drawer Track	1.0000	0.0000	0.2100
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2100	0.2100
17.27.3_Screw Tapping	8.0000	0.0000	0.8000
Screw, self-tapping	1.0000	0.1000	0.1000
17.27.4_Purchased Plywood Drawer	1.0000	0.0000	5.6520
PNW Softwood Plywood	1.0000	5.6520	5.6520
17.28_Drawer File	1		8.4430
17.28.1_Guide Drawer Track	1.0000	0.0000	0.2100
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2100	0.2100
17.28.2_Guide Drawer Track	1.0000	0.0000	0.2100
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2100	0.2100
17.28.3_Screw Tapping	8.0000	0.0000	0.8000
Screw, self-tapping	1.0000	0.1000	0.1000
17.28.4_Purchased Plywood Drawer	1.0000	0.0000	7.2230
PNW Softwood Plywood	1.0000	7.2230	7.2230
17.29_Pin Dowel	4		0.4000
Red oak I, US	1.0000	0.1000	0.1000
17.30_Hardware Package	1		1.3440
17.30.1_Tray	1	0	0.5300
Polystyrene (high impact) (HIPS)	1.0000	0.5300	0.5300
17.30.2_Support Accessory	3	0	0.0000
17.30.3_Rail	1	0	0.5000
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.5000	0.5000
17.30.4_Divider Drawer	2	0	0.3140
Red oak I, US	1.0000	0.1570	0.1570
17.31_Screw Metric	8		0.8000
IISI, Engineering Steel, EAF Route	1.0000	0.1000	0.1000
19_BOOKLET			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	1.0000		0.0000
20_GROMMET LOCATION			
Sub-Assemblies	**# Units**	**Unit Weight**	**Total**

		(lbs)	Weight
Total	1.0000		0.0000
20.1_CablePackage	1.0000		0.0000
20.1.1_CablePackage	1		0.0000
20.1.2_Wireway	2		0.0000
21_GROMMET LOCATION			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total	0.0000		0.0000
21.1_CablePackage	1.0000		0.0000
21.1.1_CablePackage	1		0.0000
21.1.2_Wireway	2		0.0000
PACKAGING WOOD, US			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total		12.8900	12.8900
PACKAGING CARDBOARD, US			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total		3.6560	3.6560
PACKAGING HONEYCOMB, US			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total		3.8400	3.8400
PACKAGING PAPER, US			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total		0.9960	0.9960
PACKAGING STRETCH FOIL, US			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total		0.8570	0.8570
TRAILER DIESEL FAL, US			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total		0.0000	0.0000
Trailer Diesel FAL, US			38.0600
Trailer Diesel FAL, US			8.4300
Trailer Diesel FAL, US			2.8300
Trailer Diesel FAL, US			5.7500
Trailer Diesel FAL, US			1.3100
Trailer Diesel FAL, US			1.1500
Trailer Diesel FAL, US			6.1400
Trailer Diesel FAL, US			83.9900

Slim Chair, Phase 0

1_BASE_CASTERS_CYL			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		10.0000
1.1_Casters hard (Chrome)	1		2.5000
1.1.1_Body 20mm Neck	5.0000		1.2500
Zinc I, US	1.0000	0.2500	0.2500
1.1.2_CasterWheels	5.0000		1.2500
Nylon 6	1.0000	0.2500	0.2500
1.2_Base Polished	1		5.0000
Aluminum 80% rec. B250 *	1.0000	5.0000	5.0000
1.3_Pneumatic Cylinder	1		2.5000
Steel 23% recycled B	1.0000	2.5000	2.5000
2_CHAIR CONTROL ARM STRAPS			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		6.0000

2.2 StrapAssembly Front Type 1	1		1.5000
2.2.1_ArmStrap Front	1.0000		1.5000
Steel 23% recycled B	1.0000	1.5000	1.5000
2.3_Rear Arm Strap Weldment	1		1.5000
2.3.2_ArmStrapAssembly Type2	1.0000		1.5000
2.3.2.4_Strap Arm Type2	1.0000		1.5000
Steel 23% recycled B	1.0000	1.5000	1.5000
3.2_SupportAssembly Upright	1		3.0000
3.2.1_Support Upright	1.0000		3.0000
Steel 23% recycled B	1.0000	3.0000	3.0000

4_SEAT			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		7.0000
4.1_Shell InnerSeat	1		3.0000
PP injection moulded A	1.0000	3.0100	3.0000
4.2_Shell OuterSeat	1		1.0000
PP injection moulded A	1.0000	1.0000	1.0000
4.5_Foam Molded Seat	1		2.0000
PUR flex. Block foam I	1.0000	2.0000	2.0000
4.6_Upholstery Seat	1		1.0000
Leather I, SC	1.0000	1.0000	1.0000

5_ARMS			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		6.0000
5.1_Tarm LH Polished	1		3.0000
Aluminum 80% rec. B250 *	1.0000	3.0000	3.0000
5.2_Tarm RH Polished	1		3.0000
Aluminum 80% rec. B250 *	1.0000	3.0000	3.0000
6_BACK MECHANISM			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		9.0000
6.1_BackAssembly High	1		7.5000
6.1.1_BackMechanism High	1.0000	0.0000	2.0000
6.1.1.3_Tube CrossStretcher	1.0000	0.0000	2.0000
Steel 23% recycled B	1.0000	2.0000	2.0000
6.1.2_Weldment Link Inner	1.0000	0.0000	3.0000
6.1.2.1_Link Inner RH	1.0000	0.0000	1.5000
Steel 23% recycled B	1.0000	1.5000	1.5000
6.1.2.2_Link Inner LH	1.0000	0.0000	1.5000
Steel 23% recycled B	1.0000	1.5000	1.5000

6.1.3_Weldment Link Upper HighBack	1.0000	0.0000	2.5000
6.1.3.3_BackWire	1.0000	0.0000	2.5000
Steel 23% recycled B	1.0000	2.5000	2.5000
6.3_UpperBackAssembly NonHeadrest	1		1.5000
6.3.1_UpperBack	1.0000	0.0000	1.5000
PNW Softwood Plywood	1.0000	1.5000	1.5000

7_BACK UPHOLSTERY FOAM			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		4.5000
7.2_Upholstery HighBack Non Headrest	1		1.5000
Leather I, SC	1.0000	1.5000	1.5000
7.4_Foam HighBack Front	1		1.5000
PUR flex. Block foam I	1.0000	1.5000	1.5000
7.5_Foam HighBack Rear	1		1.5000
PUR flex. Block foam I	1.0000	1.5000	1.5000

Slim Chair, Phase 1

1_BASE_CASTERS_CYL			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		10.0000
1.1_Casters hard (Chrome)	1		2.5000
1.1.1_Body 20mm Neck	5.0000		1.2500
Zinc I, US	1.0000	0.2100	0.2500
1.1.2_CasterWheels	5.0000		1.2500
Nylon 6	1.0000	0.2100	0.2500
1.2_Base Polished	1		5.0000
Steelcase Cast Aluminum	1.0000	6.0010	5.0000
1.3_Pneumatic Cylinder	1		2.5000
IISI, Engineering Steel, EAF Route	1.0000	2.3000	2.5000

2_CHAIR CONTROL ARM STRAPS			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		11.0000
2.1 ChairControl assy	1		1.5000
2.1.5_PneuLever	1.0000		0.2500
IISI, Rebar, EAF Route	1.0000	0.2620	0.2500
2.1.14_Weldment SeatMount	1.0000		1.2500
2.1.14.1_SeatPivotBracket	1.0000		1.2500
GS-10Ni6 I, US	1.0000	1.3310	1.2500
2.2 StrapAssembly Front Type 1	1		1.5000
2.2.1_ArmStrap Front	1.0000		1.5000
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.7840	1.5000

2.3_Rear Arm Strap Weldment	1		1.5000
2.3.2_ArmStrapAssembly Type2	1.0000		1.5000
2.3.2.4_Strap Arm Type2	1.0000		1.5000
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.7840	1.5000
3.1_HousingAssembly Bushing	1		1.5000
3.1.1_Housing Control Chair	1.0000		1.5000
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.8100	1.5000
3.2_SupportAssembly Upright	1		3.0000
3.2.1_Support Upright	1.0000		3.0000
IISI, Finished Cold Rolled Coil, BF Route	1.0000	2.7570	3.0000
3.5_Spring Torsion LeftHand	1		1.0000
IISI, Rebar, EAF Route	1.0000	0.9200	1.0000
3.6_Spring Torsion RightHand	1		1.0000
IISI, Rebar, EAF Route	1.0000	0.9200	1.0000

4_SEAT			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		7.0000
4.1_Shell InnerSeat	1		3.0000
Polypropylene (PP) Injection Molding	1.0000	3.0100	3.0000
4.2_Shell OuterSeat	1		1.0000
Polypropylene (PP) Injection Molding	1.0000	0.8480	1.0000
4.5_Foam Molded Seat	1		2.0000
Polyurethane Flexible Foam	1.0000	2.0280	2.0000
4.6_Upholstery Seat	1		1.0000
Leather I, SC	1.0000	0.7940	1.0000
5_ARMS			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		6.0000
5.1_Tarm LH Polished	1		3.0000
Steelcase Cast Aluminum	1.0000	2.8720	3.0000
5.2_Tarm RH Polished	1		3.0000
Steelcase Cast Aluminum	1.0000	2.8720	3.0000
6_BACK MECHANISM			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		9.0000
6.1_BackAssembly High	1		7.5000

6.1.1_BackMechanism High	1.0000	0.0000	2.0000
6.1.1.3_Tube CrossStretcher	1.0000	0.0000	2.0000
IISI, Steel Section, EAF Route	1.0000	1.8370	2.0000
6.1.2_Weldment Link Inner	1.0000	0.0000	3.0000
6.1.2.1_Link Inner RH	1.0000	0.0000	1.5000
GS-10Ni6 I, US	1.0000	1.3010	1.5000
6.1.2.2_Link Inner LH	1.0000	0.0000	1.5000
GS-10Ni6 I, US	1.0000	1.3010	1.5000
6.1.3_Weldment Link Upper HighBack	1.0000	0.0000	2.5000
6.1.3.3_BackWire	1.0000	0.0000	2.5000
IISI, Rebar, EAF Route	1.0000	2.6340	2.5000

6.3_UpperBackAssembly NonHeadrest	1		1.5000
6.3.1_UpperBack	1.0000	0.0000	1.5000
PNW Softwood Plywood	1.0000	1.4270	1.5000
7_BACK UPHOLSTERY FOAM			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		5.2500
7.1_DimatrolAssembly	1		0.7500
7.1.1_Dimatrol	1.0000	0.0000	0.2500
Polyester fabric I, SC	1.0000	0.2500	0.2500
7.1.3_Channel Side RH	1.0000	0.0000	0.2500
Polypropylene (PP) Injection Molding	1.0000	0.1470	0.2500
7.1.4_Channel Side LH	1.0000	0.0000	0.2500
Polypropylene (PP) Injection Molding	1.0000	0.1470	0.2500
7.2_Upholstery HighBack Non Headrest	1		1.5000
Leather I, SC	1.0000	1.3670	1.5000
7.4_Foam HighBack Front	1		1.5000
Polyurethane Flexible Foam	1.0000	1.5210	1.5000
7.5_Foam HighBack Rear	1		1.5000
Polyurethane Flexible Foam	1.0000	1.5210	1.5000

Slim Chair, Phase 2

1_BASE_CASTERS_CYL			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		11.2860
1.1_Casters hard (Chrome)	1		2.9850
1.1.1_Body 20mm Neck	5.0000		1.0500
Zinc I, US	1.0000	0.2100	0.2100
1.1.2_CasterWheels	5.0000		1.5500
Nylon 6	1.0000	0.2100	0.3100
1.1.3_Pintle	5.0000		0.3850
IISI, Engineering Steel, EAF Route	1.0000	0.2100	0.0770
1.2_Base Polished	1		6.0010
Steelcase Cast Aluminum	1.0000	6.0010	6.0010
1.3_Pneumatic Cylinder	1		2.3000
IISI, Engineering Steel, EAF Route	1.0000	2.3000	2.3000
2_CHAIR CONTROL ARM STRAPS			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		14.8850
2.1 ChairControl assy	1		2.2870
2.1.1_PneuHandle Anti RattlePad	1.0000		0.0000
2.1.2_PneuHandle Anti RattleGrommet	1.0000		0.0000
2.1.3_PneuHandle Anti ClickPad	1.0000		0.0000
2.1.4_PneuKnob	1.0000		0.0000
2.1.5_PneuLever	1.0000		0.2620
IISI, Rebar, EAF Route	1.0000	0.2620	0.2620
2.1.6_PneuAdjuster	1.0000		0.0000
2.1.7_PneuAdjuster Screw	1.0000		0.0000
2.1.8_TorqueAdjKnob	1.0000		0.0970
Nylon 6	1.0000	0.0970	0.0970
2.1.9_TorqueRodSleeve	1.0000		0.0000
2.1.10_BackLockKnob	1.0000		0.0000
2.1.11_BackLockLever	1.0000		0.2780
IISI, Rebar, EAF Route	1.0000	0.2780	0.2780
2.1.12_BackLock	1.0000		0.0860

Nylon 6/6/ Glass Fiber Composite	1.0000	0.0860	0.0860
2.1.13_BackLockLeverRetainer	1.0000		0.0000
2.1.14_Weldment SeatMount	1.0000		1.5640
2.1.14.1_SeatPivotBracket	1.0000		1.3310
GS-10Ni6 I, US	1.0000	1.3310	1.3310
2.1.14.2_Bracket ArmPivot	1.0000		0.2330
GS-10Ni6 I, US	1.0000	0.2330	0.2330
2.1.14.3_Bearing Fixed Front	1.0000		0.0000
2.1.15_Bearing SeatMount Front	1.0000		0.0000
2.1.16_Bearing SeatMount Rear	2.0000		0.0000
2.1.17_PivotPin SeatMount	2.0000		0.0000
2.1.18_Retainer PivotPin SeatMount	2.0000		0.0000
2.2 StrapAssembly Front Type 1	1		1.8350
2.2.1_ArmStrap Front	1.0000		1.7840
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.7840	1.7840
2.2.2_Pad Slide Front LH	1.0000		0.0000
2.2.3_Pad Slide Front RH	1.0000		0.0000
2.2.4_Spring SeatTilt	1.0000		0.0510
Glass, fiber or wool, US	1.0000	0.0510	0.0510
2.3_Rear Arm Strap Weldment	1		1.9760
2.3.1_SupportPlate RearArmStrap	2.0000		0.1920
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.0960	0.0960
2.3.2_ArmStrapAssembly Type2	1.0000		1.7840
2.3.2.1_Pad RearSlide RH	1.0000		0.0000
2.3.2.2_Pad RearSlide LH	1.0000		0.0000
2.3.2.3_Rivet Shoulder FlatHead	2.0000		0.0000
2.3.2.4_Strap Arm Type2	1.0000		1.7840
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.7840	1.7840
2.4_PowerPackAssembly	1		0.0000
3.1_HousingAssembly Bushing	1		2.6050
3.1.1_Housing Control Chair	1.0000		1.8100
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.8100	1.8100
3.1.2_SupportBushing	1.0000		0.6610
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.6610	0.6610
3.1.3_Bushing HousingTapered	1.0000		0.1340
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.1340	0.1340
3.1.4_Filler Weld Wire Steel	1.0000		0.0000
3.2_SupportAssembly Upright	1		2.9250
3.2.1_Support Upright	1.0000		2.7570
IISI, Finished Cold Rolled Coil, BF Route	1.0000	2.7570	2.7570

3.2.2_Support PivotSynchro	2.0000		0.1680
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.0840	0.0840
3.3_Sleeve Axle	1		0.0000
3.4_Tube Axle	1		0.4610
IISI, Steel Section, EAF Route	1.0000	0.4610	0.4610
3.5_Spring Torsion LeftHand	1		0.9200
IISI, Rebar, EAF Route	1.0000	0.9200	0.9200
3.6_Spring Torsion RightHand	1		0.9200
IISI, Rebar, EAF Route	1.0000	0.9200	0.9200
3.7_Bracket Spring Tension	1		0.2630
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2630	0.2630
3.8_Shaft Adjustment Tension Painted	1		0.3280
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.3280	0.3280
3.9_Nut Adjustment Tension	1		0.0480
IISI, Engineering Steel, EAF Route	1.0000	0.0480	0.0480
3.10_Plate Pivot Tension	1		0.3170
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.3170	0.3170
3.11_Button Stop	2		0.0000
3.12_Bearing Axle	2		0.0000
3.13_Grease Multipurpose	0		0.0000
3.14_Bushing Bronze	1		0.0000
3.15_Rivet Pivot Tension	1		0.0000
3.16_Washer Plain Non STD Friction	2		0.0000
3.17_Washer NonStandard	1		0.0000
4_SEAT			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		6.9000
4.1_Shell InnerSeat	1		3.0100
4.1.1_T NutForSeat Inner	4.0000	0.0000	0.0000
Polypropylne (PP) Injection Molding	1.0000	3.0100	3.0100
4.2_Shell OuterSeat	1		0.8480
Polypropylene (PP) Injection Molding	1.0000	0.8480	0.8480
4.3_Screws OuterSeatAttachment	5		0.0000
4.4_Foam Topper Seat	1		0.2200
Polyurethane Flexible Foam	1.0000	0.2200	0.2200
4.5_Foam Molded Seat	1		2.0280
Polyurethane Flexible Foam	1.0000	2.0280	2.0280
4.6_Upholstery Seat	1		0.7940
Leather I, SC	1.0000	0.7940	0.7940

5_ARMS			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		6.2520
5.1_Tarm LH Polished	1		2.8720
Steelcase Cast Aluminum	1.0000	2.8720	2.8720
5.2_Tarm RH Polished	1		2.8720
Steelcase Cast Aluminum	1.0000	2.8720	2.8720
5.3_Screws TArmCapAttachment	8		0.0000
5.4_Upholstery TArmCap	2		0.2000
Leather I, SC	1.0000	0.1000	0.1000
5.6_TArmCap Molded	2		0.3080
5.6.1_TArmCapInner	2.0000	0.0000	0.2640
Polypropylene (PP) Injection Molding	1.0000	0.1320	0.1320
Polyurethane Flexible Foam	1.0000	0.0440	0.0440
5.7_Screw ArmAttachment	6		0.0000

6_BACK MECHANISM			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		16.7840
6.1_BackAssembly High	1		15.1460
6.1.1_BackMechanism High	1.0000	0.0000	4.0830
6.1.1.1_Weldment BackAttachment	1.0000	0.0000	0.0000
6.1.1.2_Tube BackMounting	2.0000	0.0000	0.7200
IISI, Steel Section, EAF Route	1.0000	0.3600	0.3600
6.1.1.3_Tube CrossStretcher	1.0000	0.0000	1.8370
IISI, Steel Section, EAF Route	1.0000	1.8370	1.8370
6.1.1.4_Link LowerInner RH	1.0000	0.0000	0.2780
GS-10Ni6 I, US	1.0000	0.2780	0.2780
6.1.1.5_Link LowerInner LH	1.0000	0.0000	0.2780
GS-10Ni6 I, US	1.0000	0.2780	0.2780
6.1.1.6_Link LowerOuter	2.0000	0.0000	0.9700
GS-10Ni6 I, US	1.0000	0.4850	0.4850
6.1.2_Weldment Link Inner	1.0000	0.0000	4.2750
6.1.2.1_Link Inner RH	1.0000	0.0000	1.3010
GS-10Ni6 I, US	1.0000	1.3010	1.3010
6.1.2.2_Link Inner LH	1.0000	0.0000	1.3010
GS-10Ni6 I, US	1.0000	1.3010	1.3010
6.1.2.3_CrossMember Middle	1.0000	0.0000	0.3720
IISI, Rebar, EAF Route	1.0000	0.3720	0.3720
6.1.2.4_CrossMember Lower	1.0000	0.0000	0.3910
IISI, Rebar, EAF Route	1.0000	0.3910	0.3910
6.1.2.5_Flange InnerLink RH	1.0000	0.0000	0.4550

GS-10Ni6 I, US	1.0000	0.4550	0.4550
6.1.2.6_Flange InnerLink LH	1.0000	0.0000	0.4550
GS-10Ni6 I, US	1.0000	0.4550	0.4550
6.1.3_Weldment Link Upper HighBack	1.0000	0.0000	4.3010
6.1.3.1_CrossMember Upper	1.0000	0.0000	0.4040
IISI, Rebar, EAF Route	1.0000	0.4040	0.4040
6.1.3.2_Bracket BeltAttachment	3.0000	0.0000	0.0000
6.1.3.3_BackWire	1.0000	0.0000	2.6340
IISI, Rebar, EAF Route	1.0000	2.6340	2.6340
6.1.3.4_Link Upper Inner RH	1.0000	0.0000	0.1320
GS-10Ni6 I, US	1.0000	0.1320	0.1320
6.1.3.5_Link Upper Inner LH	1.0000	0.0000	0.1350
GS-10Ni6 I, US	1.0000	0.1350	0.1350
6.1.3.7_Link Upper Outer	2.0000	0.0000	0.3780
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.1890	0.1890
6.1.3.8_Bracket InnerBack	2.0000	0.0000	0.6180
GS-10Ni6 I, US	1.0000	0.3090	0.3090
6.1.4_Bushing Main	6.0000	0.0000	0.0000
6.1.5_Bushing Lower	2.0000	0.0000	0.0000
6.1.6_Washer Pivot	8.0000	0.0000	0.0000
6.1.7_Rivet Main	6.0000	0.0000	0.2400
IISI, Engineering Steel, EAF Route	1.0000	0.0400	0.0400
6.1.8_Rivet Lower	2.0000	0.0000	0.0000
6.1.9_Spring	2.0000	0.0000	0.2660
IISI, Rebar, EAF Route	1.0000	0.1330	0.1330
6.1.10_Bearing Spring	4.0000	0.0000	0.0000
6.1.11_BumperStop	4.0000	0.0000	0.0000
6.1.12_Link Outer RH	1.0000	0.0000	0.6150
GS-10Ni6 I, US	1.0000	0.6150	0.6150
6.1.13_Link Outer LH	1.0000	0.0000	0.6150
GS-10Ni6 I, US	1.0000	0.6150	0.6150
6.1.14_Bracket InnerBack	2.0000	0.0000	0.6180
GS-10Ni6 I, US	1.0000	0.3090	0.3090
6.2_Shield LowerLink	2		0.0000
6.3_UpperBackAssembly NonHeadrest	1		1.4270
6.3.1_UpperBack	1.0000	0.0000	1.4270
PNW Softwood Plywood	1.0000	1.4270	1.4270
6.3.2_T Nuts	4.0000	0.0000	0.0000
6.4_Screws UpperBackAttachment	4		0.0000
6.5_StapleStrip	1		0.2110
PNW Softwood Plywood	1.0000	0.2110	0.2110
6.6_Screw StapleStripRetaining	2		0.0000

7_BACK UPHOLSTERY FOAM			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		5.3570
7.1_DimatrolAssembly	1		0.8160
7.1.1_Dimatrol	1.0000	0.0000	0.2500
Polyester fabric I, SC	1.0000	0.2500	0.2500
7.1.2_Dring	2.0000	0.0000	0.0000
7.1.3_Channel Side RH	1.0000	0.0000	0.1470
Polypropylene (PP) Injection Molding	1.0000	0.1470	0.1470
7.1.4_Channel Side LH	1.0000	0.0000	0.1470
Polypropylene (PP) Injection Molding	1.0000	0.1470	0.1470
7.1.5_Extrusion J Top	1.0000	0.0000	0.0680
Polypropylene (PP) Injection Molding	1.0000	0.0680	0.0680
7.1.6_Extrusion J	3.0000	0.0000	0.2040
Polypropylene (PP) Injection Molding	1.0000	0.0680	0.0680
7.2_Upholstery HighBack Non Headrest	1		1.3670
Leather I, SC	1.0000	1.3670	1.3670
7.3_Foam Topper HighBack	1		0.1320
Polyurethane Flexible Foam	1.0000	0.1320	0.1320
7.4_Foam HighBack Front	1		1.5210
Polyurethane Flexible Foam	1.0000	1.5210	1.5210
7.5_Foam HighBack Rear	1		1.5210
Polyurethane Flexible Foam	1.0000	1.5210	1.5210

Slim Chair, Phase 3

1_BASE_CASTERS_CYL			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		11.2860
1.1_Casters hard (Chrome)	1		2.9850
1.1.1_Body 20mm Neck	5.0000		1.0500
Zinc I, US	1.0000	0.2100	0.2100
Cast work, non-ferro, US			0.2100
1.1.2_CasterWheels	5.0000		1.5500
Nylon 6	1.0000	0.2100	0.3100
Injection moulding, US			0.3100
1.1.3_Pintle	5.0000		0.3850
IISI, Engineering Steel, EAF Route	1.0000	0.2100	0.0770
Cold transforming steel, US			0.0770
1.2_Base Polished	1		6.0010
Steelcase Cast Aluminum	1.0000	6.0010	6.0010
1.3_Pneumatic Cylinder	1		2.3000
IISI, Engineering Steel, EAF Route	1.0000	2.3000	2.3000

Machining steel, US			0.2300
2_CHAIR CONTROL ARM STRAPS			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		14.8850
2.1 ChairControl assy	1		2.2870
2.1.1_PneuHandle Anti RattlePad	1.0000		0.0000
2.1.2_PneuHandle Anti RattleGrommet	1.0000		0.0000
2.1.3_PneuHandle Anti ClickPad	1.0000		0.0000
2.1.4_PneuKnob	1.0000		0.0000
2.1.5_PneuLever	1.0000		0.2620
IISI, Rebar, EAF Route	1.0000	0.2620	0.2620
Cold transforming steel, US			0.2620
2.1.6_PneuAdjuster	1.0000		0.0000
2.1.7_PneuAdjuster Screw	1.0000		0.0000
2.1.8_TorqueAdjKnob	1.0000		0.0970
Nylon 6	1.0000	0.0970	0.0970
Injection moulding, US			0.0970
2.1.9_TorqueRodSleeve	1.0000		0.0000
2.1.10_BackLockKnob	1.0000		0.0000
2.1.11_BackLockLever	1.0000		0.2780
IISI, Rebar, EAF Route	1.0000	0.2780	0.2780
Cold transforming steel, US			0.2780
2.1.12_BackLock	1.0000		0.0860
Nylon 6/6/ Glass Fiber Composite	1.0000	0.0860	0.0860
Injection moulding, US			0.0860
2.1.13_BackLockLeverRetainer	1.0000		0.0000
2.1.14_Weldment SeatMount	1.0000		1.5640
2.1.14.1_SeatPivotBracket	1.0000		1.3310
GS-10Ni6 I, US	1.0000	1.3310	1.3310
2.1.14.2_Bracket ArmPivot	1.0000		0.2330
GS-10Ni6 I, US	1.0000	0.2330	0.2330
2.1.14.3_Bearing Fixed Front	1.0000		0.0000
2.1.15_Bearing SeatMount Front	1.0000		0.0000
2.1.16_Bearing SeatMount Rear	2.0000		0.0000
2.1.17_PivotPin SeatMount	2.0000		0.0000
2.1.18_Retainer PivotPin SeatMount	2.0000		0.0000
2.2 StrapAssembly Front Type 1	1		1.8350
2.2.1_ArmStrap Front	1.0000		1.7840
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.7840	1.7840
Mech. Press, SC avg.			1.0000
2.2.2_Pad Slide Front LH	1.0000		0.0000
2.2.3_Pad Slide Front RH	1.0000		0.0000
2.2.4_Spring SeatTilt	1.0000		0.0510
Glass, fiber or wool, US	1.0000	0.0510	0.0510

2.3_Rear Arm Strap Weldment	1		1.9760
2.3.1_SupportPlate RearArmStrap	2.0000		0.1920
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.0960	0.0960
Cutting steel laser, US			0.0030
2.3.2_ArmStrapAssembly Type2	1.0000		1.7840
2.3.2.1_Pad RearSlide RH	1.0000		0.0000
2.3.2.2_Pad RearSlide LH	1.0000		0.0000
2.3.2.3_Rivet Shoulder FlatHead	2.0000		0.0000
2.3.2.4_Strap Arm Type2	1.0000		1.7840
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.7840	1.7840
Mech. Press, SC avg.			1.0000
2.4_PowerPackAssembly	1		0.0000
3.1_HousingAssembly Bushing	1		2.6050
3.1.1_Housing Control Chair	1.0000		1.8100
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.8100	1.8100
Mech. Press, SC avg.			1.0000
3.1.2_SupportBushing	1.0000		0.6610
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.6610	0.6610
Mech. Press, SC avg.			1.0000
3.1.3_Bushing HousingTapered	1.0000		0.1340
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.1340	0.1340
Mech. Press, SC avg.			1.0000
3.1.4_Filler Weld Wire Steel	1.0000		0.0000
3.2_SupportAssembly Upright	1		2.9250
3.2.1_Support Upright	1.0000		2.7570
IISI, Finished Cold Rolled Coil, BF Route	1.0000	2.7570	2.7570
Mech. Press, SC avg.			1.0000
3.2.2_Support PivotSynchro	2.0000		0.1680
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.0840	0.0840
Mech. Press, SC avg.			1.0000
3.3_Sleeve Axle	1		0.0000
3.4_Tube Axle	1		0.4610
IISI, Steel Section, EAF Route	1.0000	0.4610	0.4610
Machining steel, US			0.4610
3.5_Spring Torsion LeftHand	1		0.9200
IISI, Rebar, EAF Route	1.0000	0.9200	0.9200
Cold transforming steel, US			0.9200
3.6_Spring Torsion RightHand	1		0.9200
IISI, Rebar, EAF Route	1.0000	0.9200	0.9200
Cold transforming steel, US			0.9200
3.7_Bracket Spring Tension	1		0.2630
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2630	0.2630
3.8_Shaft Adjustment Tension Painted	1		0.3280
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.3280	0.3280
Machining steel, US			0.3280
3.9_Nut Adjustment Tension	1		0.0480
IISI, Engineering Steel, EAF Route	1.0000	0.0480	0.0480
3.10_Plate Pivot Tension	1		0.3170

IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.3170	0.3170
Mech. Press, SC avg.			1.0000
3.11_Button Stop	2		0.0000
3.12_Bearing Axle	2		0.0000
3.13_Grease Multipurpose	0		0.0000
3.14_Bushing Bronze	1		0.0000
3.15_Rivet Pivot Tension	1		0.0000
3.16_Washer Plain Non STD Friction	2		0.0000
3.17_Washer NonStandard	1		0.0000
4_SEAT			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		6.9000
4.1_Shell InnerSeat	1		3.0100
4.1.1_T NutForSeat Inner	4.0000	0.0000	0.0000
Polypropylene (PP) Injection Molding	1.0000	3.0100	3.0100
4.2_Shell OuterSeat	1		0.8480
Polypropylene (PP) Injection Molding	1.0000	0.8480	0.8480
4.3_Screws OuterSeatAttachment	5		0.0000
4.4_Foam Topper Seat	1		0.2200
Polyurethane Flexible Foam	1.0000	0.2200	0.2200
4.5_Foam Molded Seat	1		2.0280
Polyurethane Flexible Foam	1.0000	2.0280	2.0280
4.6_Upholstery Seat	1		0.7940
Leather I, SC	1.0000	0.7940	0.7940
5_ARMS			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		6.2520
5.1_Tarm LH Polished	1		2.8720
Steelcase Cast Aluminum	1.0000	2.8720	2.8720
5.2_Tarm RH Polished	1		2.8720
Steelcase Cast Aluminum	1.0000	2.8720	2.8720
5.3_Screws TArmCapAttachment	8		0.0000
5.4_Upholstery TArmCap	2		0.2000
Leather I, SC	1.0000	0.1000	0.1000
5.6_TArmCap Molded	2		0.3080
5.6.1_TArmCapInner	2.0000	0.0000	0.2640
Polypropylene (PP) Injection Molding	1.0000	0.1320	0.1320
Polyurethane Flexible Foam	1.0000	0.0440	0.0440
5.7_Screw ArmAttachment	6		0.0000
6_BACK MECHANISM			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		16.9170
6.1_BackAssembly High	1		15.2790
6.1.1_BackMechanism High	1.0000	0.0000	4.0830
6.1.1.1_Weldment BackAttachment	1.0000	0.0000	0.0000

6.1.1.2_Tube BackMounting	2.0000	0.0000	0.7200
IISI, Steel Section, EAF Route	1.0000	0.3600	0.3600
Cutting steel laser, US			0.1000
6.1.1.3_Tube CrossStretcher	1.0000	0.0000	1.8370
IISI, Steel Section, EAF Route	1.0000	1.8370	1.8370
Cold transforming steel, US			1.8370
6.1.1.4_Link LowerInner RH	1.0000	0.0000	0.2780
GS-10Ni6 I, US	1.0000	0.2780	0.2780
6.1.1.5_Link LowerInner LH	1.0000	0.0000	0.2780
GS-10Ni6 I, US	1.0000	0.2780	0.2780
6.1.1.6_Link LowerOuter	2.0000	0.0000	0.9700
GS-10Ni6 I, US	1.0000	0.4850	0.4850
6.1.2_Weldment Link Inner	1.0000	0.0000	4.2750
6.1.2.1_Link Inner RH	1.0000	0.0000	1.3010
GS-10Ni6 I, US	1.0000	1.3010	1.3010
6.1.2.2_Link Inner LH	1.0000	0.0000	1.3010
GS-10Ni6 I, US	1.0000	1.3010	1.3010
6.1.2.3_CrossMember Middle	1.0000	0.0000	0.3720
IISI, Rebar, EAF Route	1.0000	0.3720	0.3720
Cold transforming steel, US			0.3720
6.1.2.4_CrossMember Lower	1.0000	0.0000	0.3910
IISI, Rebar, EAF Route	1.0000	0.3910	0.3910
Cold transforming steel, US			0.3910
6.1.2.5_Flange InnerLink RH	1.0000	0.0000	0.4550
GS-10Ni6 I, US	1.0000	0.4550	0.4550
6.1.2.6_Flange InnerLink LH	1.0000	0.0000	0.4550
GS-10Ni6 I, US	1.0000	0.4550	0.4550
6.1.3_Weldment Link Upper HighBack	1.0000	0.0000	4.3010
6.1.3.1_CrossMember Upper	1.0000	0.0000	0.4040
IISI, Rebar, EAF Route	1.0000	0.4040	0.4040
Cold transforming steel, US			0.4040
6.1.3.2_Bracket BeltAttachment	3.0000	0.0000	0.0000
6.1.3.3_BackWire	1.0000	0.0000	2.6340
IISI, Rebar, EAF Route	1.0000	2.6340	2.6340
Cold transforming steel, US			2.6340
6.1.3.4_Link Upper Inner RH	1.0000	0.0000	0.1320
GS-10Ni6 I, US	1.0000	0.1320	0.1320
6.1.3.5_Link Upper Inner LH	1.0000	0.0000	0.1350
GS-10Ni6 I, US	1.0000	0.1350	0.1350
6.1.3.7_Link Upper Outer	2.0000	0.0000	0.3780
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.1890	0.1890
Cutting steel laser, US			0.0056
6.1.3.8_Bracket InnerBack	2.0000	0.0000	0.6180
GS-10Ni6 I, US	1.0000	0.3090	0.3090
6.1.4_Bushing Main	6.0000	0.0000	0.0000
6.1.5_Bushing Lower	2.0000	0.0000	0.0000
6.1.6_Washer Pivot	8.0000	0.0000	0.0000
6.1.7_Rivet Main	6.0000	0.0000	0.2400

IISI, Engineering Steel, EAF Route	1.0000	0.0400	0.0400
Cold transforming steel, US			0.0400
6.1.8_Rivet Lower	2.0000	0.0000	0.0000
6.1.9_Spring	2.0000	0.0000	0.2660
IISI, Rebar, EAF Route	1.0000	0.1330	0.1330
Cold transforming steel, US			0.1330
6.1.10_Bearing Spring	4.0000	0.0000	0.0000
6.1.11_BumperStop	4.0000	0.0000	0.0000
6.1.12_Link Outer RH	1.0000	0.0000	0.6150
GS-10Ni6 I, US	1.0000	0.6150	0.6150
6.1.13_Link Outer LH	1.0000	0.0000	0.6150
GS-10Ni6 I, US	1.0000	0.6150	0.6150
6.1.14_Bracket InnerBack	2.0000	0.0000	0.6180
GS-10Ni6 I, US	1.0000	0.3090	0.3090
6.2_Shield LowerLink	2		0.0000
6.3_UpperBackAssembly NonHeadrest	1		1.4270
6.3.1_UpperBack	1.0000	0.0000	1.4270
PNW Softwood Plywood	1.0000	1.4270	1.4270
6.3.2_T Nuts	4.0000	0.0000	0.0000
6.4_Screws UpperBackAttachment	4		0.0000
6.5_StapleStrip	1		0.2110
PNW Softwood Plywood	1.0000	0.2110	0.2110
6.6_Screw StapleStripRetaining	2		0.0000
7_BACK UPHOLSTERY FOAM			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		5.3570
7.1_DimatrolAssembly	1		0.8160
7.1.1_Dimatrol	1.0000	0.0000	0.2500
Polyester fabric I, SC	1.0000	0.2500	0.2500
7.1.2_Dring	2.0000	0.0000	0.0000
7.1.3_Channel Side RH	1.0000	0.0000	0.1470
Polypropylene (PP) Injection Molding	1.0000	0.1470	0.1470
7.1.4_Channel Side LH	1.0000	0.0000	0.1470
Polypropylene (PP) Injection Molding	1.0000	0.1470	0.1470
7.1.5_Extrusion J Top	1.0000	0.0000	0.0680
Polypropylene (PP) Injection Molding	1.0000	0.0680	0.0680
7.1.6_Extrusion J	3.0000	0.0000	0.2040
Polypropylene (PP) Injection Molding	1.0000	0.0680	0.0680
7.2_Upholstery HighBack Non Headrest	1		1.3670
Leather I, SC	1.0000	1.3670	1.3670
7.3_Foam Topper HighBack	1		0.1320
Polyurethane Flexible Foam	1.0000	0.1320	0.1320
7.4_Foam HighBack Front	1		1.5210
Polyurethane Flexible Foam	1.0000	1.5210	1.5210
7.5_Foam HighBack Rear	1		1.5210
Polyurethane Flexible Foam	1.0000	1.5210	1.5210

8_MISCELLANEOUS			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		2.7070
8.1_Belt Inner	1		0.3070
Polypropylene (PP) Injection Molding	1.0000	0.3070	0.3070
8.2_PopRivet	10		0.0000
8.3_Belt Outer	1		0.1790
Polypropylene (PP) Injection Molding	1.0000	0.1790	0.1790
8.4_Screw OuterBeltRetaining	4		0.0000
8.5_Shell Back Upholstered	1		2.2210
8.5.1_Shell Back	1.0000	0.0000	1.9160
Polypropylene (PP) Injection Molding	1.0000	1.9160	1.9160
8.5.2_Guide Belt	1.0000	0.0000	0.0550
Nylon 6	1.0000	0.0550	0.0550
Injection moulding, US			0.0550
8.5.3_Screw BeltGuideAttachment	2.0000	0.0000	0.0000
8.5.4_Foam BackShell	1.0000	0.0000	0.0000
8.5.5_Upholstery BackShell	1.0000	0.0000	0.2500
Leather I, SC	1.0000	0.2500	0.2500
8.5.6_Fastener ChristmasTree OuterBack Attach	4.0000	0.0000	0.0000
PACKAGING CARDBOARD, US			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total		9.0000	9.0000
PACKAGING PLASTIC BAG, US			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total		1.0000	1.0000

Slim Chair, Phase 4 (Full Product Profile)

1_BASE_CASTERS_CYL			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		11.2860
1.1_Casters hard (Chrome)	1		2.9850
1.1.1_Body 20mm Neck	5.0000		1.0500
Zinc I, US	1.0000	0.2100	0.2100
Cast work, non-ferro, US			0.2100
1.1.2_CasterWheels	5.0000		1.5500
Nylon 6	1.0000	0.2100	0.3100
Injection moulding, US			0.3100
1.1.3_Pintle	5.0000		0.3850
IISI, Engineering Steel, EAF Route	1.0000	0.2100	0.0770
Cold transforming steel, US			0.0770
1.2_Base Polished	1		6.0010
Steelcase Cast Aluminum	1.0000	6.0010	6.0010
1.3_Pneumatic Cylinder	1		2.3000

IISI, Engineering Steel, EAF Route	1.0000	2.3000	2.3000
Machining steel, US			0.2300
Ocean Freighter FAL			18.7700
Trailer Diesel FAL			7.3800
2_CHAIR CONTROL ARM STRAPS			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		14.8850
2.1 ChairControl assy	1		2.2870
2.1.1_PneuHandle Anti RattlePad	1.0000		0.0000
2.1.2_PneuHandle Anti RattleGrommet	1.0000		0.0000
2.1.3_PneuHandle Anti ClickPad	1.0000		0.0000
2.1.4_PneuKnob	1.0000		0.0000
2.1.5_PneuLever	1.0000		0.2620
IISI, Rebar, EAF Route	1.0000	0.2620	0.2620
Cold transforming steel, US			0.2620
2.1.6_PneuAdjuster	1.0000		0.0000
2.1.7_PneuAdjuster Screw	1.0000		0.0000
2.1.8_TorqueAdjKnob	1.0000		0.0970
Nylon 6	1.0000	0.0970	0.0970
Injection moulding, US			0.0970
2.1.9_TorqueRodSleeve	1.0000		0.0000
2.1.10_BackLockKnob	1.0000		0.0000
2.1.11_BackLockLever	1.0000		0.2780
IISI, Rebar, EAF Route	1.0000	0.2780	0.2780
Cold transforming steel, US			0.2780
2.1.12_BackLock	1.0000		0.0860
Nylon 6/6/ Glass Fiber Composite	1.0000	0.0860	0.0860
Injection moulding, US			0.0860
2.1.13_BackLockLeverRetainer	1.0000		0.0000
2.1.14_Weldment SeatMount	1.0000		1.5640
2.1.14.1_SeatPivotBracket	1.0000		1.3310
GS-10Ni6 I, US	1.0000	1.3310	1.3310
2.1.14.2_Bracket ArmPivot	1.0000		0.2330
GS-10Ni6 I, US	1.0000	0.2330	0.2330
2.1.14.3_Bearing Fixed Front	1.0000		0.0000
2.1.15_Bearing SeatMount Front	1.0000		0.0000
2.1.16_Bearing SeatMount Rear	2.0000		0.0000
2.1.17_PivotPin SeatMount	2.0000		0.0000
2.1.18_Retainer PivotPin SeatMount	2.0000		0.0000
2.2 StrapAssembly Front Type 1	1		1.8350
2.2.1_ArmStrap Front	1.0000		1.7840
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.7840	1.7840
Mech. Press, SC avg.			1.0000
2.2.2_Pad Slide Front LH	1.0000		0.0000
2.2.3_Pad Slide Front RH	1.0000		0.0000
2.2.4_Spring SeatTilt	1.0000		0.0510

Glass, fiber or wool, US	1.0000	0.0510	0.0510
2.3_Rear Arm Strap Weldment	1		1.9760
2.3.1_SupportPlate RearArmStrap	2.0000		0.1920
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.0960	0.0960
Cutting steel laser, US			0.0030
2.3.2_ArmStrapAssembly Type2	1.0000		1.7840
2.3.2.1_Pad RearSlide RH	1.0000		0.0000
2.3.2.2_Pad RearSlide LH	1.0000		0.0000
2.3.2.3_Rivet Shoulder FlatHead	2.0000		0.0000
2.3.2.4_Strap Arm Type2	1.0000		1.7840
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.7840	1.7840
Mech. Press, SC avg.			1.0000
2.4_PowerPackAssembly	1		0.0000
3.1_HousingAssembly Bushing	1		2.6050
3.1.1_Housing Control Chair	1.0000		1.8100
IISI, Finished Cold Rolled Coil, BF Route	1.0000	1.8100	1.8100
Mech. Press, SC avg.			1.0000
3.1.2_SupportBushing	1.0000		0.6610
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.6610	0.6610
Mech. Press, SC avg.			1.0000
3.1.3_Bushing HousingTapered	1.0000		0.1340
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.1340	0.1340
Mech. Press, SC avg.			1.0000
3.1.4_Filler Weld Wire Steel	1.0000		0.0000
3.2_SupportAssembly Upright	1		2.9250
3.2.1_Support Upright	1.0000		2.7570
IISI, Finished Cold Rolled Coil, BF Route	1.0000	2.7570	2.7570
Mech. Press, SC avg.			1.0000
3.2.2_Support PivotSynchro	2.0000		0.1680
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.0840	0.0840
Mech. Press, SC avg.			1.0000
3.3_Sleeve Axle	1		0.0000
3.4_Tube Axle	1		0.4610
IISI, Steel Section, EAF Route	1.0000	0.4610	0.4610
Machining steel, US			0.4610
3.5_Spring Torsion LeftHand	1		0.9200
IISI, Rebar, EAF Route	1.0000	0.9200	0.9200
Cold transforming steel, US			0.9200
3.6_Spring Torsion RightHand	1		0.9200
IISI, Rebar, EAF Route	1.0000	0.9200	0.9200
Cold transforming steel, US			0.9200
3.7_Bracket Spring Tension	1		0.2630
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.2630	0.2630
3.8_Shaft Adjustment Tension Painted	1		0.3280
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.3280	0.3280
Machining steel, US			0.3280
3.9_Nut Adjustment Tension	1		0.0480
IISI, Engineering Steel, EAF Route	1.0000	0.0480	0.0480

3.10_Plate Pivot Tension	1		0.3170
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.3170	0.3170
Mech. Press, SC avg.			1.0000
3.11_Button Stop	2		0.0000
3.12_Bearing Axle	2		0.0000
3.13_Grease Multipurpose	0		0.0000
3.14_Bushing Bronze	1		0.0000
3.15_Rivet Pivot Tension	1		0.0000
3.16_Washer Plain Non STD Friction	2		0.0000
3.17_Washer NonStandard	1		0.0000
4_SEAT			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		6.9000
4.1_Shell InnerSeat	1		3.0100
4.1.1_T NutForSeat Inner	4.0000	0.0000	0.0000
Polypropylene (PP) Injection Molding	1.0000	3.0100	3.0100
4.2_Shell OuterSeat	1		0.8480
Polypropylene (PP) Injection Molding	1.0000	0.8480	0.8480
4.3_Screws OuterSeatAttachment	5		0.0000
4.4_Foam Topper Seat	1		0.2200
Polyurethane Flexible Foam	1.0000	0.2200	0.2200
4.5_Foam Molded Seat	1		2.0280
Polyurethane Flexible Foam	1.0000	2.0280	2.0280
4.6_Upholstery Seat	1		0.7940
Leather I, SC	1.0000	0.7940	0.7940
5_ARMS			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		6.2520
5.1_Tarm LH Polished	1		2.8720
Steelcase Cast Aluminum	1.0000	2.8720	2.8720
5.2_Tarm RH Polished	1		2.8720
Steelcase Cast Aluminum	1.0000	2.8720	2.8720
5.3_Screws TArmCapAttachment	8		0.0000
5.4_Upholstery TArmCap	2		0.2000
Leather I, SC	1.0000	0.1000	0.1000
5.6_TArmCap Molded	2		0.3080
5.6.1_TArmCapInner	2.0000	0.0000	0.2640
Polypropylene (PP) Injection Molding	1.0000	0.1320	0.1320
Polyurethane Flexible Foam	1.0000	0.0440	0.0440
5.7_Screw ArmAttachment	6		0.0000
6_BACK MECHANISM			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		16.9170
6.1_BackAssembly High	1		15.2790
6.1.1_BackMechanism High	1.0000	0.0000	4.0830

6.1.1.1_Weldment BackAttachment	1.0000	0.0000	0.0000
6.1.1.2_Tube BackMounting	2.0000	0.0000	0.7200
IISI, Steel Section, EAF Route	1.0000	0.3600	0.3600
Cutting steel laser, US			0.1000
6.1.1.3_Tube CrossStretcher	1.0000	0.0000	1.8370
IISI, Steel Section, EAF Route	1.0000	1.8370	1.8370
Cold transforming steel, US			1.8370
6.1.1.4_Link LowerInner RH	1.0000	0.0000	0.2780
GS-10Ni6 I, US	1.0000	0.2780	0.2780
6.1.1.5_Link LowerInner LH	1.0000	0.0000	0.2780
GS-10Ni6 I, US	1.0000	0.2780	0.2780
6.1.1.6_Link LowerOuter	2.0000	0.0000	0.9700
GS-10Ni6 I, US	1.0000	0.4850	0.4850
6.1.2_Weldment Link Inner	1.0000	0.0000	4.2750
6.1.2.1_Link Inner RH	1.0000	0.0000	1.3010
GS-10Ni6 I, US	1.0000	1.3010	1.3010
6.1.2.2_Link Inner LH	1.0000	0.0000	1.3010
GS-10Ni6 I, US	1.0000	1.3010	1.3010
6.1.2.3_CrossMember Middle	1.0000	0.0000	0.3720
IISI, Rebar, EAF Route	1.0000	0.3720	0.3720
Cold transforming steel, US			0.3720
6.1.2.4_CrossMember Lower	1.0000	0.0000	0.3910
IISI, Rebar, EAF Route	1.0000	0.3910	0.3910
Cold transforming steel, US			0.3910
6.1.2.5_Flange InnerLink RH	1.0000	0.0000	0.4550
GS-10Ni6 I, US	1.0000	0.4550	0.4550
6.1.2.6_Flange InnerLink LH	1.0000	0.0000	0.4550
GS-10Ni6 I, US	1.0000	0.4550	0.4550
6.1.3_Weldment Link Upper HighBack	1.0000	0.0000	4.3010
6.1.3.1_CrossMember Upper	1.0000	0.0000	0.4040
IISI, Rebar, EAF Route	1.0000	0.4040	0.4040
Cold transforming steel, US			0.4040
6.1.3.2_Bracket BeltAttachment	3.0000	0.0000	0.0000
6.1.3.3_BackWire	1.0000	0.0000	2.6340
IISI, Rebar, EAF Route	1.0000	2.6340	2.6340
Cold transforming steel, US			2.6340
6.1.3.4_Link Upper Inner RH	1.0000	0.0000	0.1320
GS-10Ni6 I, US	1.0000	0.1320	0.1320
6.1.3.5_Link Upper Inner LH	1.0000	0.0000	0.1350
GS-10Ni6 I, US	1.0000	0.1350	0.1350
6.1.3.7_Link Upper Outer	2.0000	0.0000	0.3780
IISI, Finished Cold Rolled Coil, BF Route	1.0000	0.1890	0.1890
Cutting steel laser, US			0.0056
6.1.3.8_Bracket InnerBack	2.0000	0.0000	0.6180
GS-10Ni6 I, US	1.0000	0.3090	0.3090
6.1.4_Bushing Main	6.0000	0.0000	0.0000
6.1.5_Bushing Lower	2.0000	0.0000	0.0000
6.1.6_Washer Pivot	8.0000	0.0000	0.0000

6.1.7_Rivet Main	6.0000	0.0000	0.2400
IISI, Engineering Steel, EAF Route	1.0000	0.0400	0.0400
Cold transforming steel, US			0.0400
6.1.8_Rivet Lower	2.0000	0.0000	0.0000
6.1.9_Spring	2.0000	0.0000	0.2660
IISI, Rebar, EAF Route	1.0000	0.1330	0.1330
Cold transforming steel, US			0.1330
6.1.10_Bearing Spring	4.0000	0.0000	0.0000
6.1.11_BumperStop	4.0000	0.0000	0.0000
6.1.12_Link Outer RH	1.0000	0.0000	0.6150
GS-10Ni6 I, US	1.0000	0.6150	0.6150
6.1.13_Link Outer LH	1.0000	0.0000	0.6150
GS-10Ni6 I, US	1.0000	0.6150	0.6150
6.1.14_Bracket InnerBack	2.0000	0.0000	0.6180
GS-10Ni6 I, US	1.0000	0.3090	0.3090
6.2_Shield LowerLink	2		0.0000
6.3_UpperBackAssembly NonHeadrest	1		1.4270
6.3.1_UpperBack	1.0000	0.0000	1.4270
PNW Softwood Plywood	1.0000	1.4270	1.4270
6.3.2_T Nuts	4.0000	0.0000	0.0000
6.4_Screws UpperBackAttachment	4		0.0000
6.5_StapleStrip	1		0.2110
PNW Softwood Plywood	1.0000	0.2110	0.2110
6.6_Screw StapleStripRetaining	2		0.0000
7_BACK UPHOLSTERY FOAM			
Sub-Assemblies	**Units**	**Unit Weight (lbs)**	**Total Weight**
Total	**1.0000**		5.3570
7.1_DimatrolAssembly	1		0.8160
7.1.1_Dimatrol	1.0000	0.0000	0.2500
Polyester fabric I, SC	1.0000	0.2500	0.2500
7.1.2_Dring	2.0000	0.0000	0.0000
7.1.3_Channel Side RH	1.0000	0.0000	0.1470
Polypropylene (PP) Injection Molding	1.0000	0.1470	0.1470
7.1.4_Channel Side LH	1.0000	0.0000	0.1470
Polypropylene (PP) Injection Molding	1.0000	0.1470	0.1470
7.1.5_Extrusion J Top	1.0000	0.0000	0.0680
Polypropylene (PP) Injection Molding	1.0000	0.0680	0.0680
7.1.6_Extrusion J	3.0000	0.0000	0.2040
Polypropylene (PP) Injection Molding	1.0000	0.0680	0.0680
7.2_Upholstery HighBack Non Headrest	1		1.3670
Leather I, SC	1.0000	1.3670	1.3670
7.3_Foam Topper HighBack	1		0.1320
Polyurethane Flexible Foam	1.0000	0.1320	0.1320
7.4_Foam HighBack Front	1		1.5210
Polyurethane Flexible Foam	1.0000	1.5210	1.5210
7.5_Foam HighBack Rear	1		1.5210
Polyurethane Flexible Foam	1.0000	1.5210	1.5210
8_MISCELLANEOUS			

Sub-Assemblies	Units	Unit Weight (lbs)	Total Weight
Total	**1.0000**		2.7070
8.1_Belt Inner	1		0.3070
Polypropylene (PP) Injection Molding	1.0000	0.3070	0.3070
8.2_PopRivet	10		0.0000
8.3_Belt Outer	1		0.1790
Polypropylene (PP) Injection Molding	1.0000	0.1790	0.1790
8.4_Screw OuterBeltRetaining	4		0.0000
8.5_Shell Back Upholstered	1		2.2210
8.5.1_Shell Back	1.0000	0.0000	1.9160
Polypropylene (PP) Injection Molding	1.0000	1.9160	1.9160
8.5.2_Guide Belt	1.0000	0.0000	0.0550
Nylon 6	1.0000	0.0550	0.0550
Injection moulding, US			0.0550
8.5.3_Screw BeltGuideAttachment	2.0000	0.0000	0.0000
8.5.4_Foam BackShell	1.0000	0.0000	0.0000
8.5.5_Upholstery BackShell	1.0000	0.0000	0.2500
Leather I, SC	1.0000	0.2500	0.2500
8.5.6_Fastener ChristmasTree OuterBack Attach	4.0000	0.0000	0.0000
PACKAGING CARDBOARD, US			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total		9.0000	9.0000
PACKAGING PLASTIC BAG, US			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total		1.0000	1.0000
TRAILER DIESEL FAL, US			
Sub-Assemblies	**# Units**	**Unit Weight (lbs)**	**Total Weight**
Total			
Trailer Diesel FAL, US			21.6000