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Assessing Footwear Factories Under Emergy And Material Flow Accounting Tools After Implementing Cleaner Production Practices

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Abstract

Strategies have been developed in the last decades to improve the sustainability of produced goods, including cleaner production (CP) as an important approach in identifying problems and propose alternatives for improvement under a holistic perspective. Nova Serrana city, located at Minas Gerais state, Brazil, has a footwear cluster considered fundamental for the regional socioeconomic development. However, the production is still based on outdated management techniques that make it economically non-competitive and cause high load on the natural environment, which claims for studies supporting decisions towards higher sustainability. This work aims to discuss about the results obtained after applying the CP approach in three footwear factories located in Nova Serrana city. Additionally, the factories are assessed under emergy (with an "m") and material flow accounting tools. Results show that CP was helpful in identifying opportunities for improvement related to better management that is usually easy and cheap to be achieved, including employee training, updating internal control of material storages, reusing scrap materials, and redesigning the procedure of synthetic leather cutting. The indicators obtained from the used environmental accounting tools suggest two approaches for a decision: (i) when pursuing sustainability under a global perspective, footwear factory C should be promoted since it causes lower load on the upstream processes by demanding lower emergy (3.8 E18 sej/yr), abiotic, water and air resources (1.13 E6 kg/yr, 3.66 E7 kg/yr, and 3.82 E5 kg/yr respectively); (ii) when pursuing sustainability by considering socioeconomic short to medium needs, footwear factory B should be promoted since it has higher efficiency in producing footwear (4.03E13 sej/kg for emergy demand, 10.64 kg/kg for abiotic, 319.09 kg/kg for water and 3.96 kg/kg for air). This work contributes with practical basis for the environmental accounting and management of footwear enterprises providing important subsides for decisions.

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1 Introduction

Industry is recognized as one of the main sources of environmental pollution and resource depletion, both causing environmental burden (Herva et al., 2011a). Footwear industries have undergone great pressure regarding its environmental and social aspects, for instance, less than 5% of end-of-life shoes are recycled, and most are disposed in landfill sites around the globe (Lee and Rahimifard, 2012), added to the waste generated during its production processes.

Collaborative efforts have been made in response to these pressures, as the creation of Sustainable Apparel Coalition in 2009, a footwear and home textile industry's alliance for sustainable production (Sustainable Apparel Coalition, 2018). Over the last 20 years, the footwear industry made significant effort to improve material efficiency during the production phase, as well as eliminating the use of hazardous materials. However, the environmental gains are being overtaken by the considerable increase in the demand for footwear products (Staikos and Rahimifard, 2007). Shoes consumption increased along with world population growth and life style. According to 2014 World Footwear Annual Report (2014), the world shoes production exceeded 22 billion of pairs in 2013, with China as the major producer followed by India and Brazil. According to the Brazilian Footwear Industry Association (2016), 877 millions of shoes were produced in Brazil in 2015, from which 124 million were exported to the United States, Argentina, France and Bolivia.

Since 2013, a certification program named as Source Sustainable Program (origemsustentavel.org.br) was created to recognize those companies that incorporate sustainability issues in their productive chain. Cleaner production (CP) practices, as a useful tool to reduce waste and pollution (UNEP, 2006), have been largely applied in industries all over the world. CP opportunities can be applied from simple changes frequently requesting low costs, to more complex ones that requires innovations in equipment and/or process. Applying CP practices, some environmental and economic gains can be achieved, which calls for the use of local or global scale indicators to quantify those gains.

Several tools and indicators have been applied to assess the environmental load caused by footwear products and process. For instance, Cheah et al. (2013) evaluated the life cycle greenhouse gas emissions associated with a specific model of running shoes and investigated the drivers behind this impact. Total gas emissions accounted from cradle to grave for a pair of running shoes of synthetic material were estimated as 14 $kgCO_{2-eq.}$, including the scrap material from manufacturing phase. Most of emissions were released during shoe's material processing and manufacturing phase. Some mitigation strategies suggested by the authors were the substitution of raw materials for less carbon-intensive ones in the material processing phase, and the consolidation of adjacent parts in the manufacturing phase to reduce scrap generation. Herva et al. (2011b) estimated the ecological footprint (EF) of children's shoes including the environmental risk assessment (ERA) approach. Two models were compared, synthetic materials and leather. The leather model presented the largest EF, since raw material for leather production is a by-product of meat industry, which needs pasture land for cattle breeding. The ERA showed the presence of hazardous chemicals in both models, but values exceeded the tolerable thresholds only for the synthetic one. Considering safety as the most important criteria for children's shoes, the leather model would be preferable, especially when produced through sustainable criteria.

This work considers raw data obtained in 2013 at Nova Serrana city, Minas Gerais State, Brazil. This city is a reference for footwear production in Brazil, with more than 1,200 industries. Specifically, CP practices were applied in three different factories that participated in the "State Cleaner Production Project", which focused on the identifications of CP opportunities. To measure the obtained potential advancements after CP implementation, the environmental accounting using emergy (EM; spelled with an "m") and material flow accounting (MFA) are used as scientific tools. Both tools are scientific well recognized as important in providing subsidies towards a sustainable development; both have been used in scientific studies assessing production systems under different scales of analysis, including the industrial ones (Giannetti et al., 2013; 2015, 2016; Agostinho et al., 2015; Liu et al., 2015; Campbell, 2015; Mikulčić et al., 2016; Pan et al., 2016; Almeida et al., 2017, 2018). The goals of this study are to discuss about the obtained results after applying CP practices in three footwear factories located

Table 1 General characteristics of the three evaluated footwear factories*.

Factory	Product	Footwear production		Number of employees
		pair/month	kg/month	
A	Kids sneakers	22,132	6,639	66
B	Kids, male and female casual shoes	27,825	13,476	100
C	Male casual and soccer shoes	11,897	5,916	58

* Detailed figures at Table A.1. in Appendix.

at Nova Serrana city, Brazil, and to compare them under an environmental performance perspective by using EM and MFA tools.

2 Methods

2.1 Case studies description

Three different case studies are evaluated, each one with different profiles in terms of factory size, number of employees and products as described in Table 1. All three factories have a correct scrap and waste destination according to current Brazilian specific laws. Factory "A" produces approximately 22,000 pairs/month of sneakers for kids. It is a family-managed business, and part of the production process (specifically sewing and gluing the upper) is outsourced. The glue used is water based, minimizing human-health and environmental impacts. Factory "B" produces casual shoes for adults and kids, and male flip-flops, reaching a monthly production of 28,000 shoes. It is considered a midsize factory with high-tech equipment. Factory "C" is also family-managed and produces about 12,000 shoe pairs for boys and men per month (including soccer and casual shoes). Factory "C" has a smaller number of employees together with a lower production amount, which in absolute terms, at principle, demands lower amount of resources going into the system. Interesting to note that when taking into account the average weight for kids shoes of 0.3 kg, and for a male adult of 0.6 kg, it results in a considerable difference between factories "A" and "B" regarding their production in mass units. This claims for different basis for comparison among the studied factories, since they produce different kinds of footwear.

In general, footwear production has the six steps represented in the Figure 1. There are two main footwear components: the upper and the shoe sole. The upper component, which covers the sides and top of the footwear, has many different parts to be cut and stitched together. In the studied factories, the upper is made with synthetic materials as polyester, polyurethane, nylon and ethylene vinyl acetate (EVA). The shoe sole component can be divided into outsole and midsole, both made with thermoplastic rubber (TR) or polyvinylchloride (PVC) through molding injection. The assembling step bonds together the upper and shoe sole components, and finally the footwear is manually packed together with a shoelace.

The cutting step occurs in two kinds of presses, depending on the material size. Swing arm press is used for smaller cuts while travelling head press is used for larger ones. For economic purposes, the production of footwear with more expensive materials as natural leather must minimize waste generation, which demands investment in technology as the use of laser machines for cutting process. Although existing the best options of knives for each cutting procedures aiming to minimize trimming, during the fieldwork it was observed that cutting step results in considerable material scrap losses; to estimate the percentage of material losses, the resulting scraps were monthly collected and compared with the raw material demanded by cutting process.

The step of sewing and gluing the upper component is divided into different sewing machines that work sequentially; different sewing machines can be used depending on the task to be performed. After finishing the upper component, the quality is checked before the next step. In the region were the studied factories are located, it is usual to outsource the upper component due to economic reasons or when the factory has no enough physical space to include such process; this is the case of factory "A". However, this practice could lead to quality related

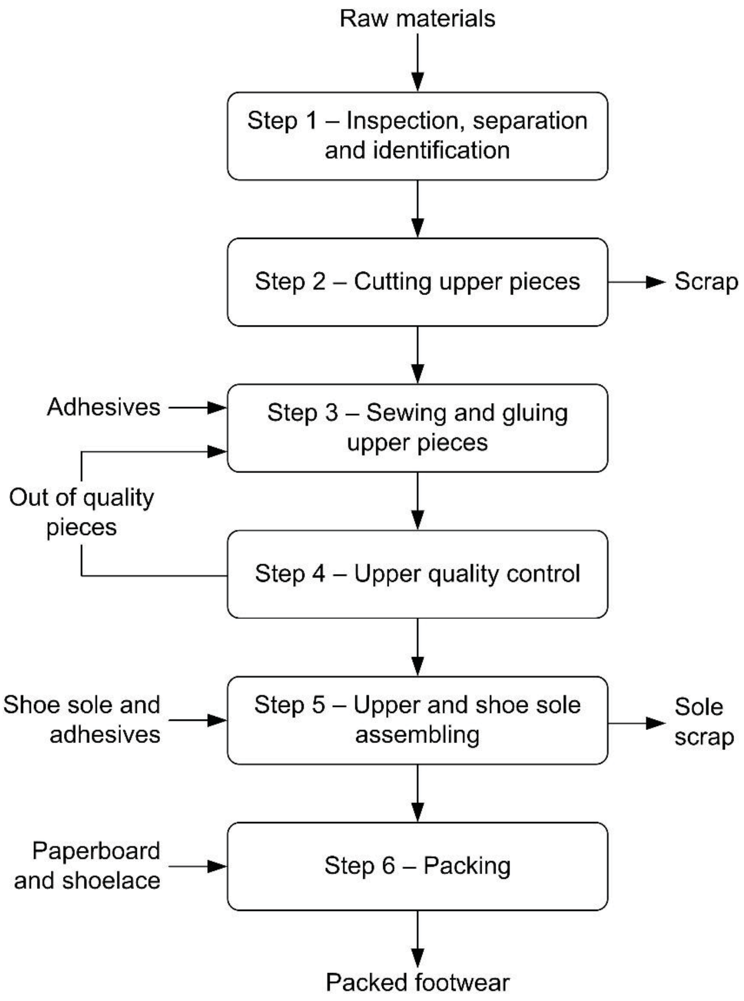

Fig. 1 General flow sheet for footwear production.

problems in the product as components stitched incorrectly, which results in loss of time, materials and money.

The assembling step is performed in order to join the upper and shoe sole components. For this step, a conveyor belt is used together with different machines for other purposes. The glue is spread over the upper and shoe sole components separately, then both pass through a drying oven and flash machine to reactivate the glue. After that, both components are pressed together and refrigerated. The shoe sole is made by molding injection, and the footwear factories in the region considered in this study usually outsources this process; this happens for the three evaluated factories. Before getting into the process, the shoe sole is cleaned up with solvent, and halogen is spread on it. At the end of processes, the insole is added, the final product is cleaned up, and a quality control is carried on before packing; the shoelace is put inside the package together with the finished footwear.

2.2 Quantifying the environmental performance of footwear factories evaluated

To support quantitative comparisons, two global scale methods for analysis were used: environmental accounting based on emergy, and material flow accounting. Both methods complement each other by identifying patterns characterized by different demands for environmental support and different balance between renewable and non-renewable input resources. These methods are extended back in time to include resource use or the environmental work needed for inputs formation (Giannetti et al., 2008). They are described individually in the next items.

Table 2 Unit emergy values (UEVs) used in this work.

Item	Unit	UEV (sej/unit)	Reference
Electricity	J	2.10 E+05	Odum, 1996
Synthetic raw materials	g	7.45 E+09	Buranakarn, 1998
Chemical adhesives	g	7.45 E+09	Buranakarn, 1998
Machines	g	1.44 E+10	Cuadra and Rydberg, 2006
Human labor	J	1.68 E+07	Demetrio, 2011

2.2.1 Emergy synthesis

Emergy is the solar energy directly or indirectly necessary to obtain a product in a process and is expressed in solar emergy joules (sej) (Odum, 1996). It measures the necessary work of nature in providing a giving resource. Emergy synthesis permits the conversion of all contributions received by the production system (e.g. metals, energy, oil, money and information) to a single base of measurement: the solar energy joule (sej). To convert energy inputs and other input flows to a production system into their solar equivalent, unit emergy values (UEVs) expressed in sej/unit are used (Almeida et al., 2013). UEVs, which are defined based on non-conservative emergy algebra (Brown and Herendeen, 1996), lead to the definition of the total emergy represented by: Emergy = UEV × available energy.

Emergy computations include renewable and non-renewable local resources, input purchase from market, the product to be sold to the market and the by-products (usually waste) released by the system. The greater is the total emergy driving a process, the greater its environmental load, because more amount of resources are needed by production system. Similarly, the system that uses less emergy to produce a given amount of product is more efficient under a global perspective (Odum, 2001).

In particular, emergy accounting offers the following useful attributes, which justify its choice in providing quantitative indicators supporting decisions towards sustainability: (1) Emergy has a rigorous scientific basis (Odum, 1996) that supports its robusteness (Giannetti et al., 2013); (2) Emergy uses the same unit (solar energy joules) to account for the direct and indirect support required by a system (Odum, 1996) - the use of a single unit avoids the step of selecting and classifying variables since scientists designated to select variables may not agree on the nature of the variables to be selected or on the relative importance of one among others (Giannetti et al., 2010); (3) Emergy can help to avoid the difficulty researchers experience in normalizing and aggregating variables having different units to construct indicators - When constructing indicators based on variables (resources, emissions, wastes, information) that are not accounted with the same unit, there is still a need of objective criteria for choosing an appropriate aggregating method to enable international comparability (Almeida et al., 2007); (4) Emergy can provide transparency in evaluating systems, as weighting factors, which are value judgments and can be prone to errors, are not employed; (5) Emergy can account directly or indirectly for the information and for the free ecological services and their contributions to system operation. Detailed information on emergy accounting method including concepts and definitions please refer to Odum (Odum, 1996).

Several authors have estimated UEVs for different products and processes, making calculations easier by consulting databases (for instance, the one provided by the emergysociety.com). In this study, UEVs were taken from scientific literature by using labeled values for each item. All UEVs used in this work are presented in Table 2. The footwear factories evaluated are quite simple regarding processes and they demand few kinds of materials that can be considered similar in their upstream production processes, which justifies the reduced amount of used UEVs.

All UEVs includes labor and services. They were derived from scientific literature that based their calculations on emergy baseline of 15.83 E24 sej/yr. As the emergy baseline was recently updated to 12 E24 sej/yr (Brown and Ulgiati, 2016), the conversion factor of 0.76 was used to update them. The UEV for human labor was estimated according to the Brazilian conditions; UEV_{labor} = 4.64 E16 sej/person yr (from Demetrio, 2011) * 1/264 yr/day * 1/2,500 person day/kcal * 1/4,186 kcal/J = 1.68 E7 sej/J.

Table 3 Material input per service unit (MIPS) used in this work.

Item	Unit for MIPS	MIPS			
		Abiotic	Water	Air	Comments
Raw materials	kg/kg	8.1	278	3.73	Polyester textile fiber
TR/PVC for shoe sole	kg/kg	5.7	146	1.65	Styrene-butadiene rubber; SBR
Adhesives	kg/kg	3.19	18.72	1.89	Chemicals: acetone & phenol
Paperboard	kg/kg	1.86	93.56	0.33	Corrugated cardboard
Electricity	kg/kWh	1.55	66.73	0.54	Electrical power, all OECD countries
Water	kg/kg	0.01	1.3	0.00	Drinking water
Machines	kg/kg	8.14	63.67	0.44	Wire rod, engineering steel

Source: Wuppertal Institute for Climate, 2014.

2.2.2 Material flow accounting

This accounting tool was developed by the Wuppertal Institute (Liedtke et al., 2002). It can evaluate the environmental harm associated with the extraction or diversion of resources from their natural ecosystem pathways. It applies the concepts of industrial ecology to study how materials and energy flow into, throughout, and out of a system (Almeida et al., 2010). The relation between material input and service obtained as output is called Material Input per Service unit (MIPS), which serves as an indicator of precautionary environmental protection. MIPS considered the use of resources from the point of their extraction from nature: all data corresponds to the amount of materials moved from nature, thus it accounts for the categories of biotic or renewable raw material, abiotic or nonrenewable raw material, water, air and soil movement in agriculture and forestry (including erosion). Material flow accounting is a tool to measure indirect load on the natural environment by demanding resources to make a product.

The used MIPS factors in this work (Table 3) were obtained from a dataset developed by Wuppertal Institute for Climate, Environment and Energy (Wuppertal Institute for Climate, 2014). This dataset provides information on the material intensity (MI) of different materials, fuels, transport services and food, listed according to the inputs categories of the MIPS concept. Since detailed information for the biotic category is scarce, it was suppressed from our calculations. Material flow accounting disregard direct and indirect labor demand (i.e. resources supporting labor) as well as direct ecosystem services supporting the process (Giannetti et al., 2015).

3 Results and discussions

3.1 Cleaner production opportunities for the studied footwear factories

High quality information is crucial to support decision towards a sustainable development, and this aspect was identified as the most deficient on the three studied footwear factories. The in-situ interviews pointed that managers still understand environmental issues as additional costs, and the main conceptual framework to lead with by-products is the end-of-pipe, currently considered as outdated and unable to support decisions towards a strong sustainable development. During fieldwork, other negative aspect identified by authors was related to low commitment of employees with the factory growth or development, as well the low level of training activities for them; both aspects contribute to the high levels of employees' turnover. Worst situation was identified in factory A, where both employees and employer did not get involved in the CP project launched by the Minas Gerais State government. This behavior created a barrier between the information donor (government) and the receiver (factory) and make difficult the application of good practices (i.e. cleaner production) in the footwear production processes that could lead the factory to be more competitive in the market.

As part of the all CP implementation project, some environmental reports were elaborated by describing the inputs of materials and energy, as well the manufacturing steps, machines and equipment, kind and amount of final products, and the generated by-products (waste). The diagnostic phase was carried out to obtain the inventory of three factories studied; this step includes material and energy balances by identifying resources flowing in and out of factory boundaries. The three studied factories use electricity from the Brazilian grid, which is about 80% from hydropower source – considered as renewable. The direct water consumption is relatively low, exclusively for employee needs including bathrooms and kitchen.

The inventory indicates the synthetic leather, used in different colors, as the main raw material (in mass units) demanded by factories. The textile fabric is precisely cut and used to make different parts of footwear, whether in the swing arm press or by the travelling head press. After that, pieces go to sewing machines, while the scrap is collected, stored, and sold to the market usually at low price. During fieldwork, a large amount of raw material scrap was identified, generated primarily at cutting step; numbers are missing here because we did not had access to precise measures. Besides an environmental concern, the large amount of scrap results also in economic warning because synthetic leather is bought for about 5 USD/kg and it is sold as scrap by 0.03 USD/kg. This claims for CP opportunities aiming to reduce the scrap generation, mainly acting on the scrap source reduction. For instance, during fieldwork it was observed that scrap generated in the travelling head presses – a machine used to cut pieces with large sizes – could be further used as raw material for the swing arm presses, a machine used to cut pieces with small size. This practical suggestion was implemented by factory B.

In Factory C, small holes are obtained from the synthetic leather by using a punching machine. The synthetic leather is purchased in rolls with standardized width of 1.4 meters, but the punching machine reaches a maximum of 1.3 meters, which results in losing of 0.1 meters width of leather. A simple CP opportunity was the division of rolls into two parts, so the punching machine was able to obtain leather holes covering the total area of synthetic leather. Instead of adding an economic cost for its implementation, this CP opportunity resulted in economic and environmental benefits. The economic benefit is related to the recovery of 0.10 m of synthetic leather per roll, while the environmental one is the reduction of the same amount of scrap totalizing savings of 0.11 kg per roll.

Other CP opportunity was the review of datasheet models. According to employees, some datasheets have incorrect information on the amount and color of textile fabric stocked. Besides losing time, this outdated datasheets leads to other problem: when a wrong color for textile fabric is bought, it usually remains stocked and, if not used after a certain period, it is sold by a lower price. Updating datasheets would save time, storage space, and money.

Comparing the productivity of the three factories, Table 1 shows higher performance for factory B when considering the footwear pairs produced (27,825 footwear pair/month). Interesting to note that factory A produces about 20% less footwear than factory B, but when considering production in mass units, this difference raises by 50%. This is because factory A produces only kid sneakers, which are smaller and lighter compared to the adult ones. Since footwear manufacturing is labor-intensive, analyzing the productivity using the number of employees can bring interesting insights. In this case, Table 4 shows that factory A has higher productivity when considering footwear pairs produced (1 employee produces 4,024 footwear pairs per year), while factory B has higher productivity when considering the production in mass units (1 employee produces 1,617 kg of footwear pairs per year). Recognizing the importance of social aspects under a more holistic perception of sustainability, factory C demands more labor to reach similar production than factories A and B, which is a positive aspect under social sphere. On the other hand, the lower productivity of factory C could lead to internal economic disturbances in a competitive market.

As highlighted before, footwear manufacturing is labor-intensive since most of the processes are manually developed, or by workers operating individual machines (Cheah et al., 2013). Thus, the characteristic of high employees' turnover identified for the three evaluated factories deserves special attention. Companies should find ways to keep their work team motivated, and for this goal, training activities would be the key to increase productivity by reducing environmental load. During fieldwork, factory B was the only that invested on training by performing weekly meetings of employees under psychologist support. This could be one reason of its higher

Table 4 Annual productivity of the three evaluated footwear factories under human labor basis.

Factory	pair/employee	kg/employee
A	4,024	1,207
B	3,339	1,617
C	2,461	1,224

Table 5 Emergy accounting table (annual basis) for footwear factory A.

Item	Unit	Value	UEV in sej/unit	Emergy in sej/yr	% of total emergy
Electricity	J	3.75 E+11	2.10 E+05	7.88 E+16	1.8
Synthetic raw materials	g	1.54 E+08	7.45 E+09	1.15 E+18	25.6
Chemical adhesives	g	9.84 E+06	7.45 E+09	7.33 E+16	1.6
Machines	g	8.33 E+06	1.44 E+10	1.20 E+17	2.7
Human labor	J	1.82 E+11	1.68 E+07	3.06 E+18	68.3
Total emergy				4.49 E+18	100.0
Input/output ratio	sej/pair	1.69 E+13			
Input/output ratio	sej/kg	5.63 E+13			

* Detailed figures at Table A.2. in Appendix.

performance for productivity in kg/employee (Table 4).

After applying the CP opportunities in the evaluated systems, their environmental performance can now be quantified to support a comparative discussion. For this purpose, emergy and material flow accounting methods are used and separately presented in the next items.

3.2 Emergy accounting

Figure 2 shows the energy diagram for the footwear factories evaluated in this work. This diagram is an essential step when applying emergy accounting because it represents a conceptual model of the evaluated systems, in which the main energy flows, interactions (processes) and components are presented to facilitate its interpretation. The same diagram represents all three evaluated systems since they are quite similar. The pathways of the energy system diagram trace the energy flows coming in from outside sources through parts, and interactions leaving the window either as an energy output to the surrounding system or as used energy. Figure 2 shows that all direct energy inputs come from the larger economy (feedback from economy), which usually are strongly dependent on non-renewable resources (fossil energy) and reduce the renewability of systems. Internal processes include all the steps as previously described in Figure 1, including cutting, sewing & gluing, assembling and packing. Systems output includes the final product (footwear) packed, and by-products as scraps (shoe sole and pieces of raw material as textile fabric).

After understanding how the systems work, the emergy accounting table was elaborated by accounting for all systems' input flows. The following items are considered: synthetic leather, vinyl foam, nylon, polyvinyl chloride (PVC), chemicals used for gluing (as adhesives and primers), paperboard used for packing, electricity, water, machines, infrastructure and human labor. At this point, and according to objectives of this study, services were not included in calculations to avoid the market influence on results (i.e., services include profitability, the brand market, image, and other subjective values); as emphasized by Ulgiati and Brown (2014) a standardized procedure is still needed to account for labor and services. Results are presented at Tables 5, 6 and 7; since our preliminary calculations for energy flows of water, infrastructure and packing resulted in insignificant values (lesser than 0.01% of total emergy), they are not shown here.

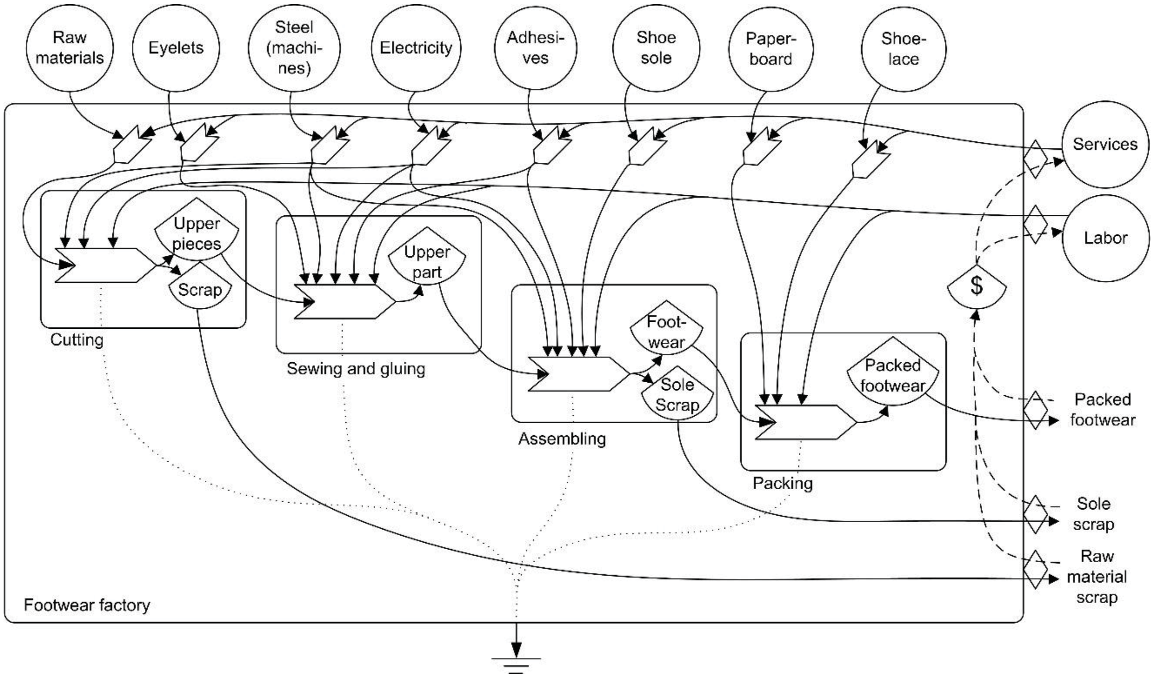

Fig. 2 Energy diagram of the evaluated footwear factories. Legend: External circles = outside energy sources (including energy, materials, labor and services); Arrowed lines = energy flows; Arrowed dashed lines = monetary flows; External rectangle = boundaries of the evaluated systems; Internal rectangles = internal processes; Large arrows = interaction among energy flows; Round base triangle = energy, material and money storages. For detailed explanation of emergy language symbols please refer to Odum (1996).

Table 6 Emergy accounting table (annual basis) for footwear factory B..

Item	Unit	Value	UEV in sej/unit	Emergy in sej/yr	% of total emergy
Electricity	J	2.41 E+11	2.10 E+05	5.05 E+16	0.8
Synthetic raw materials	g	2.05 E+08	7.45 E+09	1.52 E+18	23.7
Chemical adhesives	g	5.34 E+06	7.45 E+09	3.98 E+16	0.6
Machines	g	1.68 E+07	1.44 E+10	2.42 E+17	3.7
Human labor	J	2.76 E+11	1.68 E+07	4.64 E+18	71.2
Total emergy				6.52 E+18	100.0
Input/output ratio	sej/pair	1.95 E+13			
Input/output ratio	sej/kg	4.03 E+13			

* Detailed figures at Table A.3. in Appendix.

Tables 5 to 7 show that human labor corresponds to approximately 70% of total emergy demanded by all three factories evaluated. As the number of employees will probably remain the same due to specificities of this kind of production system, the emergy of human labor will always be expressive. However, as discussed before, the quality of work could be improved through training activities to achieve higher performance for productivity. The second most important item for all three factories is synthetic raw materials, achieving about 25% of total emergy. Due to the importance of synthetic materials in the footwear production, applying CP actions towards a reduction on their demand will also result in reduction of emergy usage, and lower global load on the environment.

Table 7 Emergy accounting table (annual basis) for footwear factory C.

Item	Unit	Value	UEV in sej/unit	Emergy in sej/yr	% of total emergy
Electricity	J	2.78 E+11	2.10 E+05	5.85 E+16	1.5
Synthetic raw materials	g	1.24 E+08	7.45 E+09	9.20 E+17	24.2
Chemical adhesives	g	2.24 E+06	7.45 E+09	1.67 E+16	0.4
Machines	g	7.71 E+06	1.44 E+10	1.11 E+17	2.9
Human labor	J	1.60 E+11	1.68 E+07	2.69 E+18	70.9
Total emergy				3.80 E+18	100.0
Input/output ratio	sej/pair	2.66 E+13			
Input/output ratio	sej/kg	5.35 E+13			

* Detailed figures at Table A.4. in Appendix.

From emergy tables, factory C can be considered as having higher performance because it demands lower annual emergy to produce footwear (3.80 E18 sej/yr). However, since the three factories have differences on kind and amount on their production (Table 1), using a functional unit is necessary to allow fair comparisons. In this sense, the emergy demanded by all factories based on mass of products (sej/kg) and the amount of footwear pairs (sej/pairs) produced is also calculated. Under mass basis, the best performance (higher efficiency) is observed by factory B (4.03 E13 sej/kg), while factories A and C have lower and similar performance. By considering the amount of footwear pairs produced, factory A (1.69 E13 sej/pair) has higher efficiency (11%) than B, while C has the lowest efficiency. Recognizing that mass of products would be a more rational parameter for comparison since all three factories produce different kind of products as well we are dealing with production systems characterized by high material demand, factory B should be supported when decisions are made towards higher degrees of sustainability. Factory B demands lower emergy – which implies in lower load on the environment – to produce the same amount (in mass units) of footwear than factories A and C.

3.3 Material flow accounting

Material intensity calculations for the three footwear evaluated factories is shown in Table 8. Material intensity represents all the indirect material embodied in the final footwear product that are not directly perceived within factories, instead, it was previously used in the upstream processes to make available the needed resources for footwear production.

In general, Table 8 shows factories' large dependence on water and raw materials (in mass units), and electricity due to electric machines used in the production processes. Raw materials include all materials directly needed to produce a footwear, and their detailed description is presented at Tables A.5-7 in Appendix. Interesting to note that, although not directly used during footwear processes, the water resource is the one largest used indirectly by all three factories, reaching values about 32 times the amount of abiotic materials; it was expected the latter as the most impacting one, since producing footwear is a quite simple process that basically assembles pieces of materials. This result emphasizes the importance in using upstream environmental assessment tools (as the emergy and material flow accounting tools as used in this work) to quantify and understand the hidden costs of production processes.

Table 8 also shows that, in absolute terms, Factory C demands lower amount of abiotic (1.13 E+06 kg/yr), water (3.66 E+07 kg/yr), and air (3.82 E+05 kg/yr) resources among the three factories evaluated. By considering these results, factory C should be promoted since it causes lower load on upstream natural environment. However, when considering productivity as a decision parameter by taking into account the factories' outputs (footwear pairs and its mass), Table 9 shows that factory B should be promoted by far. The absence of a win-win scenario claims that decisions must be performed based on a chosen target: (i) aiming lower load on the

Table 8 Material intensity results for footwear factories.

Resources demanded for footwear production			Material intensity (in kg/yr) of demanded resources		
Item	Unit/yr	Amount	Abiotic	Water	Air
Factory A					
Raw materials	kg	1.54 E+05	1.14 E+06	3.70 E+07	4.83 E+05
Adhesives	kg	9.84 E+03	3.14 E+04	1.84 E+05	1.86 E+04
Paperboard	kg	9.42 E+04	1.75 E+05	8.81 E+06	3.11 E+04
Electricity	kWh	1.04 E+05	1.62 E+05	6.95 E+06	5.63 E+04
Water	kg	3.00 E+05	3.00 E+03	3.90 E+05	-
Machines	kg	8.34 E+03	6.79 E+04	5.31 E+05	3.67 E+03
Total	-	-	1.58 E+06	5.39 E+07	5.93 E+05
Factory B					
Raw materials	kg	2.08 E+05	1.47 E+06	4.59 E+07	5.88 E+05
Adhesives	kg	5.34 E+03	1.70 E+04	9.99 E+04	1.01 E+4
Paperboard	kg	-	-	-	-
Electricity	kWh	6.69 E+04	1.04 E+05	4.46 E+06	3.61 E+04
Water	kg	8.00 E+04	8.00 E+02	1.04 E+05	-
Machines	kg	1.56 E+04	1.27 E+05	1.07 E+06	7.39 E+03
Total	-	-	1.72 E+06	5.16 E+07	6.41 E+05
Factory C					
Raw materials	kg	1.24 E+05	8.30 E+05	2.50 E+07	3.13 E+05
Adhesives	kg	2.25 E+03	7.17 E+03	4.20 E+04	4.25 E+03
Paperboard	kg	5.88 E+04	1.09 E+05	5.50 E+06	1.94 E+04
Electricity	kWh	7.73 E+04	1.20 E+05	5.16 E+06	4.18 E+04
Water	kg	3.00 E+05	3.00 E+03	3.90 E+05	-
Machines	kg	7.71 E+03	6.28 E+04	4.91 E+05	3.40 E+03
Total	-	-	1.13 E+06	3.66 E+07	3.82 E+05

* Detailed figures at Tables A.5-7 in Appendix.

Table 9 Material intensity of footwear factories relative to total production.

Factory	Abiotic		Water		Air	
	kg/pair	kg/kg	kg/pair	kg/kg	kg/pair	kg/kg
A	5.95	19.83	202.95	676.56	2.23	7.44
B	5.15	10.64	154.54	319.09	1.92	3.96
C	7.92	15.92	256.37	515.55	2.68	5.38

biosphere by ignoring economic and social aspects related to footwear production, the factory C must be promoted; (ii) considering the need for footwear by society and also recognizing the economic importance of its production, the factory B must be promoted.

4 Conclusions

The cleaner production (CP) approach applied in three Brazilian footwear factories allowed the identification of some aspects that should be overcome towards an increase on factories sustainability, including employee training, increase the commitment of factory owners with the governmental CP programs, reduce the large amount of material scrap, and make a reliable datasheet with information on materials storage. The following suggestions were implemented by the evaluated factories, which improved some of the identified negative aspects, including reuse of material scrap in other processes instead of landfilling them, and redesigning the way in which synthetic leather is cut to improve the efficiency of material usage.

After implementing CP, the applied accounting tools showed similar results that could be used for decisions with different targets: (i) focusing on the sustainability under a larger scale and temporal analysis, the absolute performance indicators show that Factory C must be promoted since it demands lower amount of emergy (3.8 E+18 sej/yr), abiotic resources (1.13 E+06 kg/yr), water (3.66 E+07 kg/yr), and air (3.82 E+05 kg/yr) than Factories A and B; (ii) on the other hand, focusing on the sustainability under a reduced temporal analysis, the relative performance indicators show that Factory B must be promoted since it demands lower amount of emergy (4.03 E+13 sej/kg), abiotic resources (10.64 kg/kg), water (319.09 kg/kg), and air (3.96 kg/kg).

The existing trade-off obtained for the performance indicators is not novelty when considering multicriteria approaches under different basis for comparison. Depending on the strategic planning pursued by stakeholders, different decisions can be derived from this work, for instance, by replacing materials with high-embodied energy (or emergy), increasing the efficiency for those most impacting processes, and improving the labor quality through training activities. The obtained results can be used by footwear factories in supporting well-based decisions towards sustainability.

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APPENDIX

Raw data and calculation notes.

Table A1 Amount and kind of footwear produced by the three evaluated factories.

Factories specificities	Footwear production	
	Pairs/month	kg/month
Factory A: kid sneakers		
Line #1	3,689	1,106
Line #2	9,111	2,733
Line #3	9,332	2,799
Total	22,132	6,639
Factory B: casual shoes		
Male	17,522	10,513
Female	1,471	662
Kids	6,066	1,819
Baby	2,325	348
Flip flops	441	132
Total	27,825	13,476
Factory B: casual shoes		
Male	7,825	4,695
Kids	1,222	366
Soccer shoes	2,850	855
Total	11,897	5,916

Table A2 Expanded emergy accounting table for footwear factory A.

Item	Unit/yr	Amount[a]	UEV[b] in sej/unit	Emergy[c] in sej/yr
1. Electricity	J	3.75 E+11	2.10 E+05	7.88 E+16
2. Raw Material (total)	g	1.54 E+08	7.45 E+09	1.15 E+18
2.1. Synthetic leather	g	4.09 E+07	7.45 E+09	3.05 E+17
2.2. Synthetic suede	g	3.29 E+07	7.45 E+09	2.45 E+17
2.3. EVA rubber	g	1.81 E+07	7.45 E+09	1.35 E+17
2.4. Thermoplastic Polymer	g	2.88 E+05	7.45 E+09	2.15 E+15
2.5. Nylon	g	1.12 E+06	7.45 E+09	8.31 E+15
2.6. Synthetic Lining	g	5.17 E+06	7.45 E+09	3.85 E+16
2.7. Insole foam	g	5.46 E+06	7.45 E+09	4.07 E+16
2.8. TNT	g	1.42 E+06	7.45 E+09	1.05 E+16
2.9. Toe Puff (thermoplastic)	g	4.51 E+06	7.45 E+09	3.36 E+16
2.10. TR/PVC for sole	g	4.45 E+07	7.45 E+09	3.31 E+17
3. Chemicals (total)	g	9.84 E+06	7.45 E+09	7.33 E+16
3.1. Spray glue	g	6.30 E+06	7.45 E+09	4.69 E+16
3.2. Glue	g	1.08 E+06	7.45 E+09	8.05 E+15
3.3. Halogen	g	3.60 E+05	7.45 E+09	2.68 E+15
3.4. Solvent	g	2.10 E+06	7.45 E+09	1.56 E+16
4. Machines (total)	g	8.34 E+06	1.44 E+10	1.20 E+17
4.1. Die Cutting press	g	5.73 E+06	1.44 E+10	8.24 E+16
4.2. Toe cap transfer	g	1.25 E+05	1.44 E+10	1.80 E+15
4.3. Sewing machine	g	8.59 E+05	1.44 E+10	1.24 E+16
4.4. Conveyor belt	g	3.00 E+05	1.44 E+10	4.32 E+15
4.5. Flash machine	g	1.50 E+05	1.44 E+10	2.16 E+15
4.6. Drying oven	g	3.25 E+05	1.44 E+10	4.68 E+15
4.7. Press	g	3.00 E+05	1.44 E+10	4.32 E+15
4.8. Shaper Refrigerator	g	3.10 E+05	1.44 E+10	4.46 E+15
4.9. Halogen Cabin	g	5.60 E+04	1.44 E+10	8.06 E+14
4.10. Air compressor	g	1.86 E+05	1.44 E+10	2.68 E+15
5. Human Labor	J	1.82 E+11	1.68 E+07	3.06 E+18

[a] 1. Electricity = 104,222 kWh/yr (data obtained in situ) * 3.60 E6 J/kWh = 3.75 E11 J/yr; 2. Raw material (total) and 3. Chemicals (total) = data obtained from surveys in situ; 4. Machines (total) = amount and weight of equipments from surveys in situ divided by their lifetimes of 40 years; 5. Human labor = 66 employees * 2,500 kcal/day employee * 4,186 J/kcal * 264 day/yr = 1.82 E11 J/yr.

[b] UEVS sources (please refer also to Table 2 in the main text): electricity (Odum, 1996), synthetic raw materials (Buranakarn, 1998), chemical adhesives (Buranakarn, 1998), machines (Cuadra and Rydberg, 2006) and human labor (Demetrio, 2011).

[c] Emergy = Amount * UEV.

Table A3 Expanded emergy accounting table for footwear factory B.

Item	Unit/yr	Amount[a]	UEV[b] in sej/unit	Emergy[c] in sej/yr
1. Electricity	J	2.41 E+11	2.10 E+05	5.05 E+16
2. Raw Material (total)	g	2.08 E+08	7.45 E+09	1.55 E+18
2.1. Synthetic leather	g	6.94 E+07	7.45 E+09	5.17 E+17
2.2. EVA rubber	g	1.98 E+07	7.45 E+09	1.48 E+17
2.3. Thermoplastic Polymer	g	2.33 E+06	7.45 E+09	1.74 E+16
2.4. Synthetic Lining	g	1.06 E+06	7.45 E+09	7.87 E+15
2.5. Insole foam	g	4.38 E+06	7.45 E+09	3.26 E+16
2.6. Toe Puff (thermoplastic)	g	1.78 E+07	7.45 E+09	1.33 E+17
2.7. TR/PVC for sole	g	8.98 E+07	7.45 E+09	6.69 E+17
2.8. Foam	g	2.95 E+06	7.45 E+09	2.20 E+16
3. Chemicals (total)	g	5.34 E+06	7.45 E+09	3.98 E+16
3.1. Spray glue	g	3.99 E+06	7.45 E+09	2.97 E+16
3.2. Glue	g	5.63 E+05	7.45 E+09	4.19 E+15
3.3. Halogen	g	4.26 E+05	7.45 E+09	3.17 E+15
3.4. Solvent	g	3.60 E+05	7.45 E+09	2.68 E+15
4. Machines (total)	g	1.68 E+07	1.44 E+10	2.42 E+17
4.1. Die Cutting press	g	1.07 E+07	1.44 E+10	1.54 E+17
4.2. Toe cap transfer	g	1.25 E+05	1.44 E+10	1.80 E+15
4.3. Sewing machine	g	1.70 E+06	1.44 E+10	2.45 E+16
4.4. Conveyor belt	g	6.00 E+05	1.44 E+10	8.64 E+15
4.5. Flash machine	g	3.00 E+05	1.44 E+10	4.32 E+15
4.6. Drying oven	g	6.50 E+05	1.44 E+10	9.36 E+15
4.7. Press	g	4.50 E+05	1.44 E+10	6.48 E+15
4.8. Shaper Refrigerator	g	6.20 E+05	1.44 E+10	8.93 E+15
4.9. Halogen Cabin	g	1.12 E+05	1.44 E+10	1.61 E+15
4.10. Air compressor	g	3.72 E+05	1.44 E+10	5.36 E+15
4.11. Steamer	g	2.20 E+05	1.44 E+10	3.17 E+15
4.12. Pneumatic Shoehorn	g	2.60 E+04	1.44 E+10	3.74 E+14
4.13. Dryer	g	9.60 E+05	1.44 E+10	1.38 E+16
5. Human Labor	J	2.76 E+11	1.68 E+07	4.64 E+18

[a] 1. Electricity = 66,850 kWh/yr (data obtained in situ) * 3.60 E6 J/kWh = 2.41 E11 J/yr; 2. Raw material (total) and 3. Chemicals (total) = data obtained from surveys in situ; 4. Machines (total) = amount and weight of equipments from surveys in situ divided by their lifetimes; 5. Human labor = 100 employees * 2,500 kcal/day employee * 4,186 J/kcal * 264 day/yr = 2.76 E11 J/yr.

[b] UEVS sources (please refer also to Table 2 in the main text): electricity (Odum, 1996), synthetic raw materials (Buranakarn, 1998), chemical adhesives (Buranakarn, 1998), machines (Cuadra and Rydberg, 2006) and human labor (Demetrio, 2011).

[c] Emergy = Amount * UEV.

Table A4 Expanded emergy accounting table for footwear factory C.

Item	Unit/yr	Amount[a]	UEV[b] in sej/unit	Emergy[c] in sej/yr
1. Electricity	J	2.78 E+11	2.10 E+05	5.85 E+16
2. Raw Material (total)	g	1.24 E+08	7.45 E+09	9.20 E+17
2.1. Synthetic leather	g	2.77 E+07	7.45 E+09	2.06 E+17
2.2. Synthetic suede	g	1.16 E+06	7.45 E+09	8.61 E+15
2.3. EVA rubber	g	4.40 E+06	7.45 E+09	3.28 E+16
2.4. Thermoplastic Polymer	g	1.32 E+06	7.45 E+09	9.83 E+15
2.5. Nylon	g	5.22 E+05	7.45 E+09	3.89 E+15
2.6. Synthetic Lining	g	2.17 E+06	7.45 E+09	1.61 E+16
2.7. Insole foam	g	1.06 E+07	7.45 E+09	7.87 E+16
2.8. Toe Puff (thermoplastic)	g	3.65 E+06	7.45 E+09	2.72 E+16
2.9. TR/PVC for sole	g	7.08 E+07	7.45 E+09	5.27 E+17
2.10. Foam	g	1.27 E+06	7.45 E+09	9.43 E+15
3. Chemicals (total)	g	2.25 E+06	7.45 E+09	1.67 E+16
3.1. Spray glue	g	8.40 E+05	7.45 E+09	6.26 E+15
3.2. Glue	g	5.39 E+05	7.45 E+09	4.01 E+15
3.3. Halogen	g	5.80 E+05	7.45 E+09	4.32 E+15
3.4. Solvent	g	2.88 E+05	7.45 E+09	2.15 E+15
4. Machines (total)	g	7.71 E+06	1.44 E+10	1.11 E+17
4.1. Die Cutting press	g	4.94 E+06	1.44 E+10	7.11 E+16
4.2. Toe cap transfer	g	1.25 E+05	1.44 E+10	1.80 E+15
4.3. Sewing machine	g	8.95 E+05	1.44 E+10	1.29 E+16
4.4. Conveyor belt	g	3.00 E+05	1.44 E+10	4.32 E+15
4.5. Drying oven	g	3.25 E+05	1.44 E+10	4.68 E+15
4.6. Press	g	1.50 E+05	1.44 E+10	2.16 E+15
4.7. Shaper Refrigerator	g	3.10 E+05	1.44 E+10	4.46 E+15
4.8. Halogen Cabin	g	5.60 E+04	1.44 E+10	8.06 E+14
4.9. Air compressor	g	3.72 E+05	1.44 E+10	5.36 E+15
4.10. Upper Shaper	g	2.40 E+05	1.44 E+10	3.46 E+15
5. Human Labor	J	1.60 E+11	1.68 E+07	2.69 E+18

[a] 1. Electricity = 77,320 kWh/yr (data obtained in situ) * 3.60 E6 J/kWh = 2.78 E11 J/yr; 2. Raw material (total) and 3. Chemicals (total) = data obtained from surveys in situ; 4. Machines (total) = amount and weight of equipments from surveys in situ divided by their lifetimes; 5. Human labor = 66 employees * 2,500 kcal/day employee * 4,186 J/kcal * 264 day/yr = 1.60 E11 J/yr.

[b] UEVS sources (please refer also to Table 2 in the main text): electricity (Odum, 1996), synthetic raw materials (Buranakarn, 1998), chemical adhesives (Buranakarn, 1998), machines (Cuadra and Rydberg, 2006) and human labor (Demetrio, 2011).

[c] Emergy = Amount * UEV.

Table A5 Expanded table for material intensity calculation of footwear factory A.

Item	Unit/yr	Value	Material intensity in kg/yr		
			Abiotic	Water	Air
Raw Material	kg	1.54 E+05	1.14 E+06	3.70 E+07	4.83E+05
Synthetic leather	kg	4.09 E+04	3.32 E+05	1.14 E+07	1.53 E+05
Synthetic suede	kg	3.29 E+04	2.66 E+05	9.15 E+06	1.23 E+05
EVA rubber	kg	1.81 E+04	1.46 E+05	5.02 E+06	6.74 E+04
Thermoplastic Polymer	kg	2.88 E+02	2.33 E+03	8.01 E+04	1.07 E+03
Nylon	kg	1.12 E+03	9.04 E+03	3.10 E+05	4.16 E+03
Synthetic Lining	kg	5.17 E+03	4.19 E+04	1.44 E+06	1.93 E+04
Insole foam	kg	5.46 E+03	4.42 E+04	1.52 E+06	2.04 E+04
TNT	kg	1.42 E+03	1.15 E+04	3.94 E+05	5.28 E+03
Toe Puff (thermoplastic)	kg	4.51 E+03	3.66 E+04	1.25 E+06	1.68 E+04
TR/PVC for sole	kg	4.45 E+04	2.53 E+05	6.49 E+06	7.34 E+04
Chemicals	kg	9.84 E+03	3.14 E+04	1.84 E+05	1.86 E+04
Spray glue	kg	6.30 E+03	2.01 E+04	1.18 E+05	1.19 E+04
Glue	kg	1.08 E+03	3.45 E+03	2.02 E+04	2.04 E+03
Halogen	kg	3.60 E+02	1.15 E+03	6.74 E+03	6.80 E+02
Solvent	kg	2.10 E+03	6.70 E+03	3.93 E+04	3.97 E+03
Paperboard	kg	9.42 E+04	1.75 E+05	8.81 E+06	3.11 E+04
Electricity	kWh	1.04 E+05	1.62 E+05	6.95 E+06	5.63 E+04
Water	kg	3.00 E+05	3.00 E+03	3.90 E+05	0.0 E+00
Machines	kg	8.34 E+03	6.79 E+04	5.31 E+05	3.67 E+03
Die Cutting press	kg	5.73 E+03	4.66 E+04	3.65 E+05	2.52 E+03
Toe cap transfer	kg	1.25 E+02	1.02 E+03	7.96 E+03	5.50 E+01
Sewing machine	kg	8.59 E+02	6.99 E+03	5.47 E+04	3.78 E+02
Conveyor belt	kg	3.00 E+02	2.44 E+03	1.91 E+04	1.32 E+02
Flash machine	kg	1.50 E+02	1.22 E+03	9.55 E+03	6.60 E+01
Drying oven	kg	3.25 E+02	2.65 E+03	2.07 E+04	1.43 E+02
Press	kg	3.00 E+02	2.44 E+03	1.91 E+04	1.32 E+02
Shaper Refrigerator	kg	3.10 E+02	2.52 E+03	1.97 E+04	1.36 E+02
Halogen Cabin	kg	5.60 E+01	4.56 E+02	3.57 E+03	2.46 E+01
Air compressor	kg	1.86 E+02	1.51 E+03	1.18 E+04	8.18 E+01

Table A6 Expanded table for material intensity calculation of footwear factory B

Item	Unit/yr	Value	Material intensity in kg/yr		
			Abiotic	Water	Air
Raw Material	kg	2.08 E+05	1.47 E+06	4.59 E+07	5.88 E+05
Synthetic leather	kg	6.94 E+04	5.62 E+05	1.93 E+07	2.59 E+05
EVA rubber	kg	1.98 E+04	1.60 E+05	5.51 E+06	7.39 E+04
Thermoplastic Polymer	kg	2.33 E+03	1.89 E+04	6.48 E+05	8.70 E+03
Synthetic Lining	kg	1.06 E+03	8.56 E+03	2.94 E+05	3.94 E+03
Insole foam	kg	4.38 E+03	3.55 E+04	1.22 E+06	1.63 E+04
Toe Puff (thermoplastic)	kg	1.78 E+04	1.44 E+05	4.96 E+06	6.65 E+04
TR/PVC for sole	kg	8.98 E+04	5.12 E+05	1.31 E+07	1.48 E+05
Foam	kg	2.95 E+03	2.39 E+04	8.21 E+05	1.10 E+04
Chemicals	kg	5.34 E+03	1.70 E+04	9.99 E+04	1.01 E+04
Spray glue	kg	3.99 E+03	1.27 E+04	7.47 E+04	7.54 E+03
Glue	kg	5.63 E+02	1.80 E+03	1.05 E+04	1.06 E+03
Halogen	kg	4.26 E+02	1.36 E+03	7.97 E+03	8.05 E+02
Solvent	kg	3.60 E+02	1.15 E+03	6.74 E+03	6.80 E+02
Electricity	kWh	6.69 E+04	1.04 E+05	4.46 E+6	3.61 E+04
Water	kg	8.00 E+04	8.00 E+02	1.04 E+05	0
Machines	kg	1.56 E+04	1.27 E+05	1.07 E+06	7.39 E+03
Die Cutting press	kg	1.07 E+04	8.68 E+04	6.79 E+05	4.69 E+03
Toe cap transfer	kg	1.25 E+02	1.02 E+03	7.96 E+03	5.50 E+01
Sewing machine	kg	1.70 E+03	1.38 E+04	1.08 E+05	7.47 E+02
Conveyor belt	kg	6.00 E+02	4.88 E+03	3.82 E+04	2.64 E+02
Flash machine	kg	3.00 E+02	2.44 E+03	1.91 E+04	1.32 E+02
Drying oven	kg	6.50 E+02	5.29 E+03	4.14 E+04	2.86 E+02
Press	kg	4.50 E+02	3.66 E+03	2.87 E+04	1.98 E+02
Shaper Refrigerator	kg	6.20 E+02	5.05 E+03	3.95 E+04	2.73 E+02
Halogen Cabin	kg	1.12 E+02	9.12 E+02	7.13 E+03	4.93 E+01
Air compressor	kg	3.72 E+02	3.03 E+03	2.37 E+04	1.64 E+02
Steamer	kg	2.20 E+02	2.28 E+02	1.40 E+04	9.68 E+01
Pneumatic Shoehorn	kg	2.60 E+01	3.41 E+01	1.66 E+03	1.14 E+01
Dryer	kg	9.60 E+02	9.68 E+02	6.11 E+04	4.22 E+02

Table A7 Expanded table for material intensity calculation of footwear factory C

Item	Unit/yr	Value	Material intensity in kg/yr		
			Abiotic	Water	Air
Raw Material	kg	1.24 E+05	8.30 E+05	2.50 E+07	3.13 E+05
Synthetic leather	kg	2.77 E+04	2.24 E+05	7.69 E+06	1.03E+05
Synthetic suede	kg	1.16 E+03	9.36 E+03	3.21 E+05	4.31 E+03
EVA rubber	kg	4.40 E+03	3.57 E+04	1.22 E+06	1.64 E+04
Thermoplastic Polymer	kg	1.32 E+03	1.07 E+04	3.67 E+05	4.92 E+03
Nylon	kg	5.22 E+02	4.23 E+03	1.45 E+05	1.95 E+03
Synthetic Lining	kg	2.17 E+03	1.76 E+04	6.02 E+05	8.08 E+03
Insole foam	kg	1.06 E+04	8.56 E+04	2.94 E+06	3.94 E+04
Toe Puff (thermoplastic)	kg	3.65 E+03	2.95 E+04	1.01 E+06	1.36 E+04
TR/PVC for sole	kg	7.08 E+04	4.04 E+05	1.03 E+07	1.17 E+05
Foam	kg	1.27 E+03	1.03 E+04	3.52 E+05	4.72 E+03
Chemicals	kg	2.25 E+03	7.17 E+03	4.20 E+04	4.25 E+03
spray glue	kg	8.40 E+02	2.68 E+03	1.57 E+04	1.59 E+03
glue	kg	5.39 E+02	1.72 E+03	1.01 E+04	1.02 E+03
halogen	kg	5.80 E+02	1.85 E+03	1.09 E+04	1.10 E+03
solvent	kg	2.88 E+02	9.19 E+02	5.39 E+03	5.44 E+02
Paperboard	kg	5.88 E+04	1.09 E+05	5.50 E+06	1.94 E+04
Electricity	kWh	7.73 E+04	1.20 E+05	5.16 E+06	4.18 E+04
Water	kg	3.00 E+05	3.00 E+03	3.90 E+05	0.0E+00
Machines	kg	7.7E+03	6.28 E+04	4.91 E+05	3.39 E+03
Die Cutting press	kg	4.94 E+03	4.02 E+04	3.15 E+05	2.17 E+03
Toe cap transfer	kg	1.25 E+02	1.02 E+03	7.96 E+03	5.50 E+01
Sewing machine	kg	8.95 E+02	7.29 E+03	5.70 E+04	3.94 E+02
Conveyor belt	kg	3.00 E+02	2.44 E+03	1.91 E+04	1.32 E+02
Drying oven	kg	3.25 E+02	2.65 E+03	2.07 E+04	1.43 E+02
Press	kg	1.50 E+02	1.22 E+03	9.55 E+03	6.60 E+01
Shaper Refrigerator	kg	3.10 E+02	2.52 E+03	1.97 E+04	1.36 E+02
Halogen Cabin	kg	5.60 E+01	4.56 E+02	3.57 E+03	2.46 E+01
Air compressor	kg	3.72 E+02	3.03 E+03	2.37 E+04	1.64 E+02
Upper Shaper	kg	2.40 E+02	1.95 E+03	1.53 E+04	1.06 E+02