Environmental performance evaluation – a new tool for the industry

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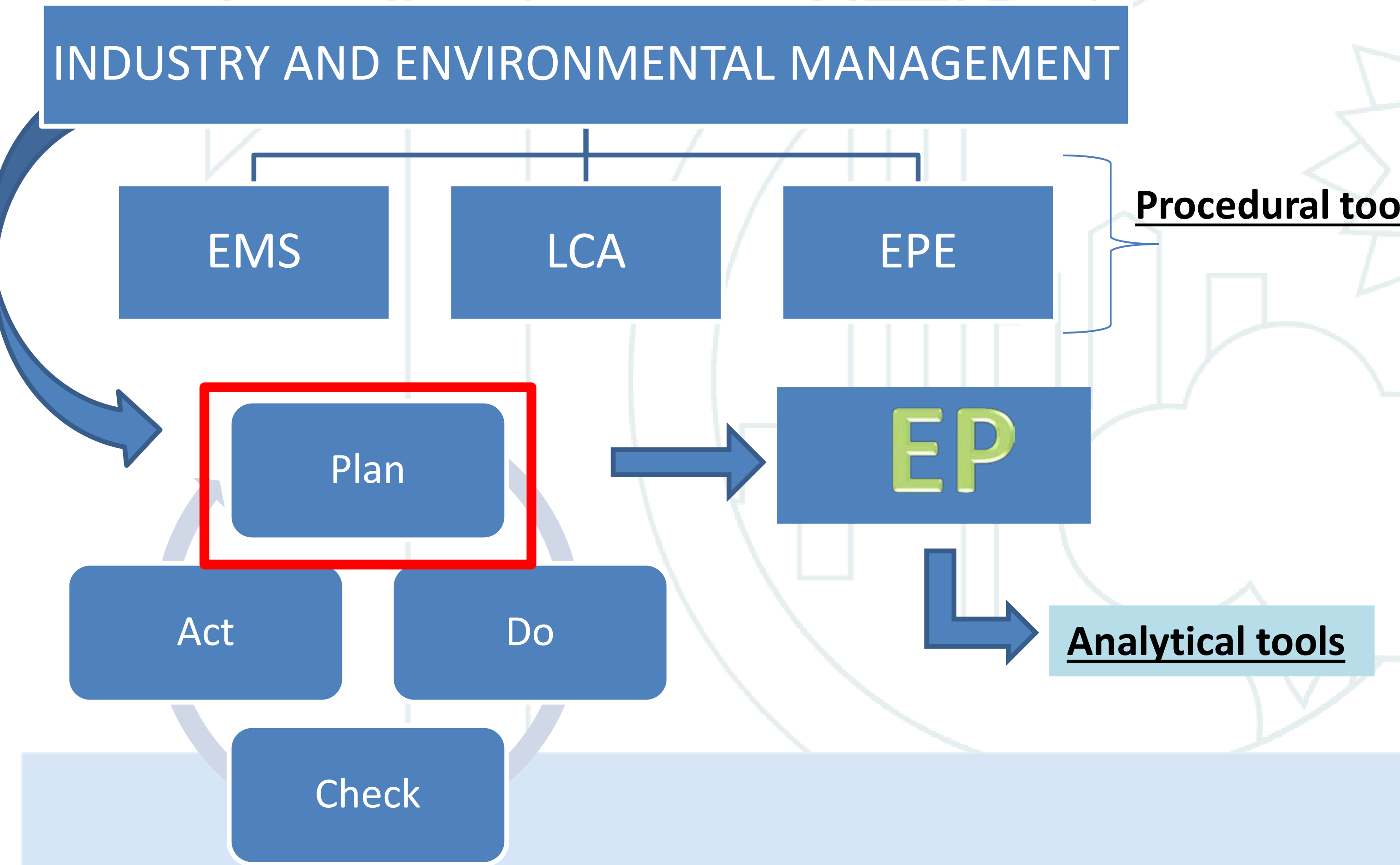
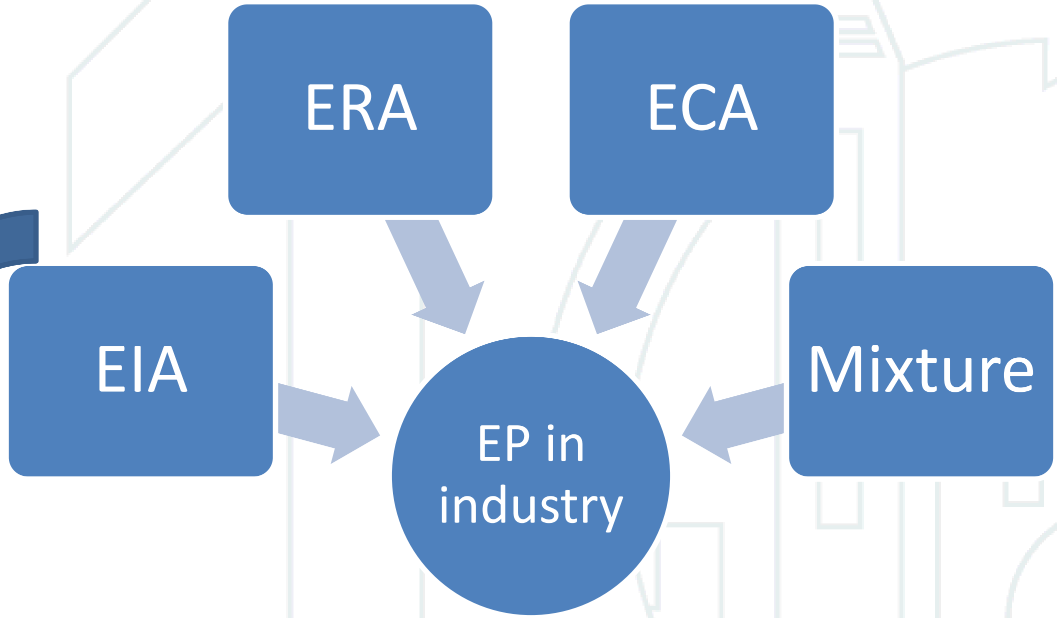
Introduction of article origin

- Main result of the doctorate;
- Development of a practical tool to guide decisions in the search for environmental improvements by industry;
- Important contribution to the state of the art of environmental performance studies;

1. Introduction



1. Introduction



- Products and services
- Substances
- Company / industry
- Nations or regions
- Policies, plans and projects

Finnveden e Moberg (2005)

Angelakoglou and Gaidajis (2015), da Silva and Amaral (2009) and Hermann *et al.* (2007) cited the lack of EPE analytical tool suitable to help decision-makers in the search for environmental improvements.

Aim

This study aimed to build and test a new analytical tool to efficiently evaluate environmental performance of industrial processes, mainly those with low environmental maturity. This analytical tool was named EPIP (Environmental Performance of Industrial Processes).

2. Methodology

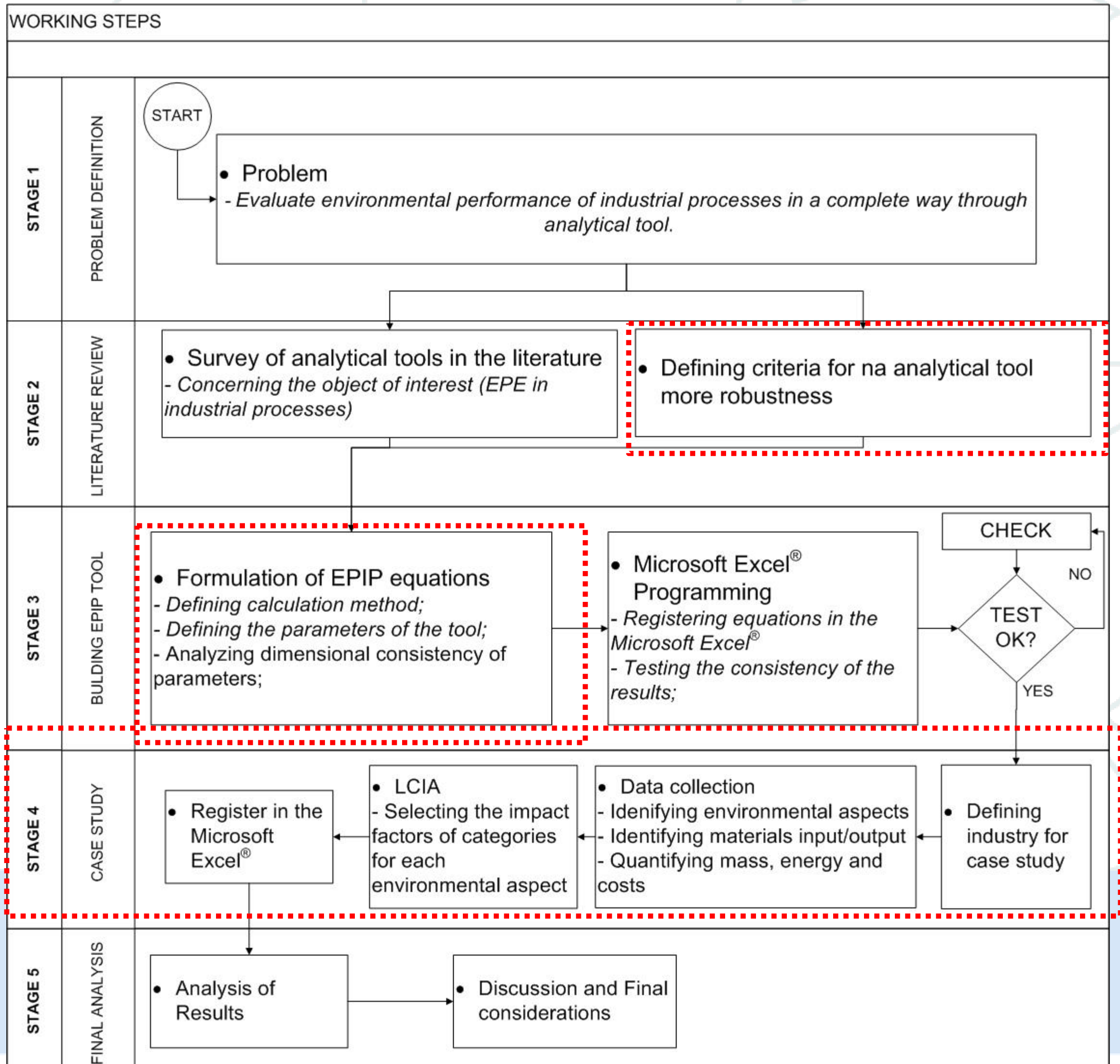


Fig. 1. Flowchart of EPIP tool building.

2. Methodology

- Criteria selected: based on a large literature survey, considering Standards, guidelines and analytical tools;
- Variables and equations:
  - Economic analysis: based in MFCA and LCC tools.
  - Environmental analysis: based in MFCA and LCIA tools
- Case study (manufacturing industry packaging yogurt cup) in order to assess the effectiveness of EPIP tool

3. Results and discussion

3.1. Selection of EPIP's criteria

- I. amount of inputs-outputs materials (Material Balance);
- II. consumption/production of Energy (Energy Balance);
- III. solid, liquid and gaseous emissions, and final destination of solid waste;
- IV. environmental Impact Assessment;
- V. environmental Costs (material, energy and emissions);
- VI. legal compliance and stakeholder requirements;
- VII. surrounding environment condition; and
- VIII. applied measures to prevent pollution (investment costs and/or adoption of procedural tools to reduce environmental impact).

Note: some authors consider the externalities costs in the environmental performance evaluation (da Silva and Amaral, 2009; Jasch, 2003). However, a significant uncertainty is assigned to this criterion (da Silva and Amaral, 2009) and hence, this criterion was not selected for the EPIP tool.

3. Results and discussion

3.2. Definition of EPIP's variables and equations

- Main equation → **Cost of the Environmental Aspect**

$$CEA(n) = [MLC(n) + CEC(n) + MDC(n) + EMC(n)] \cdot [IM(n) + IE(n)] = EcG(n).EnG(n)$$

- Economic analysis group

$$MLC(n) = ML_{1_x m}(n) \cdot MC_{m_x 1}(n)$$

→ **Material Loss Cost**

$$CEC(n) = CE(n) \cdot EUC(n) \cdot PE(n) = CE(n) \cdot EUC(n) \cdot \frac{M_{OUT}(n)}{M_{IN}(n)}$$

→ **Consumed Energy Cost**

$$MDC(n) = M_{OUT}(n) \cdot \left[D^{\%}_{1_x d}(n).WD_{d_x d}\right] \cdot DC_{d_x 1}(n)$$

→ **Material Destination Cost**

$$EMC(n) = TCE \cdot \frac{M_{OUT}(n)}{MEA} = TCE \cdot \frac{M_{OUT}(n)}{\sum_{n=1}^{N} M_{OUT}(n)}$$

→ **Environmental Management Cost**

3. Results and discussion

3.2. Definition of EPIP's variables and equations

- Main equation → **Cost of the Environmental Aspect**

$$CEA(n) = [MLC(n) + CEC(n) + MDC(n) + EMC(n)] \cdot [IM(n) + IE(n)] = EcG(n).EnG(n)$$

- Environmental analysis group

$$IM(n) = M_{OUT}(n).\sum_{j=1}^{k}\left[W_j.\frac{IC_j(n)}{N_j}\right]$$ → **Impact of Materials**

$$IE(n) = CE(n).PE(n).\sum_{j=1}^{k}\left[W_j.\frac{IC_j(n)}{N_j}\right]$$ → **Impact of Energy**

3. Results and discussion

3.2. Definition of EPIP's variables and equations

Tab. 1. Impact categories considered in the environmental analysis group by EPIP.

Impact category	Reference methods for impact category	Normalization factor	Normalization Reference
Human toxicity	IMPACT2002+	219 kg chloroethylene into air$_{-eq}$/pers.y	(Jolliet et al., 2003)
Respiratory effects	IMPACT2002+	8.80 kg $PM_{2.5}$ into air$_{-eq}$/pers.y	(Jolliet et al., 2003)
Ionizing radiation	IMPACT2002+	5.33E05 Bq Carbon-14 into air$_{-eq}$/pers.y	(Jolliet et al., 2003)
Ozone layer depletion	IMPACT2002+	0.204 kg CFC-11 into air$_{-eq}$/pers.y	(Jolliet et al., 2003)
Photochemical oxidation	IMPACT2002+	12.4 kg ethylene into air$_{-eq}$/pers.y	(Jolliet et al., 2003)
Global warming	IMPACT2002+	11.600 kg CO_2 into air$_{-eq}$/pers.y	(Jolliet et al., 2003)
Aquatic ecotoxicity	IMPACT2002+	1.36E06 kg triethylene glycol into water$_{-eq}$/pers.y	(Jolliet et al., 2003)
Terrestrial ecotoxicity	IMPACT2002+	1.20E06 kg triethylene glycol into soil$_{-eq}$/pers.y	(Jolliet et al., 2003)
Aquatic acidification	IMPACT2002+	66.20 kg SO_2 into air$_{-eq}$/pers.y	(Jolliet et al., 2003)
Aquatic eutrophication	IMPACT2002+	14.30 kg PO^{4}_{3-} into water$_{-eq}$/pers.y	(Jolliet et al., 2003)
Terrestrial acidification / nutrification	IMPACT2002+	315 kg SO_2 into air$_{-eq}$/pers.y	(Jolliet et al., 2003)
Bulk waste	EDIP 2003	1726 kg bulk waste$_{-eq}$ /pers.y	(Eurostat, 2015)
Hazardous waste	EDIP 2003	180 kg hazardous waste$_{-eq}$/pers.y	(Eurostat, 2015)
Water scarcity index (WSI)	Water footprint	365000 kg water withdrawal$_{-eq}$/pers.y	(Jolliet et al., 2003)
Non-renewable energy	Cumulative Energy Demand	3320 kg crude oil$_{-eq}$/pers.y or 152000 MJ/pers.y	(Jolliet et al., 2003)
Renewable energy	Cumulative Energy Demand	152000 MJ/pers.y	(Jolliet et al., 2003)
Mineral extraction	IMPACT2002+	5730 kg iron (in ore)$_{-eq}$/pers.y	(Jolliet et al., 2003)

Years
2007 - 2017

3. Results and discussion

3.2. Definition of EPIP's variables and equations

- Weighting factors

I. selection of the weighting factors already present in the Eco-Indicator 99, if there is unsuitable knowledge of the quality of the industry surrounding environment to perform its own weight;

II. selection to obtain the damage weighting factors, by applying the Analytical Hierarchy Process (AHP), which is a multi-criteria method that compares and ranks impact categories by levels of importance.

3. Results and discussion

3.3. Stages of EPIP tool application in the general industrial processes

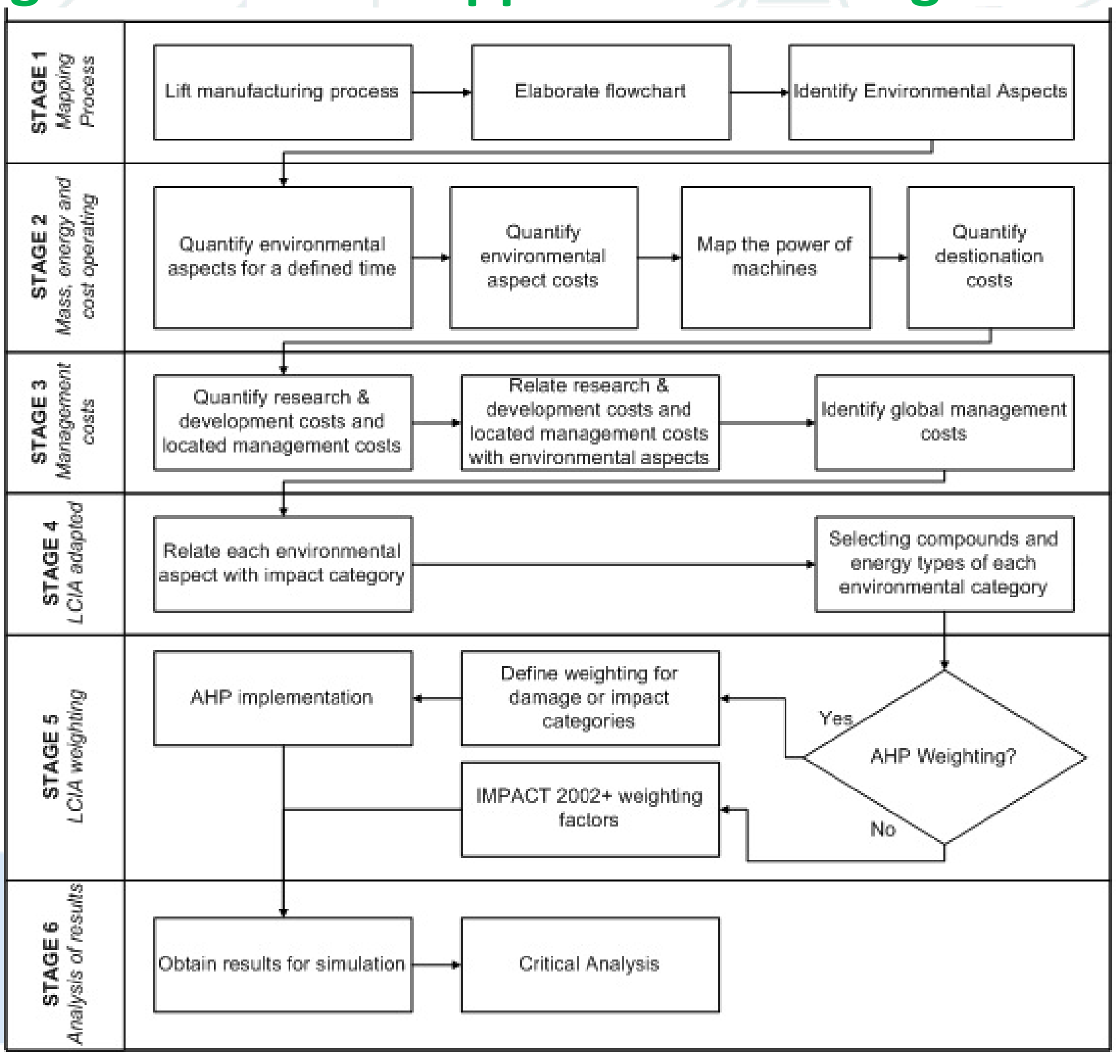


Fig. 2. Flowchart of EPIP tool application in general industrial processes.

4. Application of EPIP tool in Case study

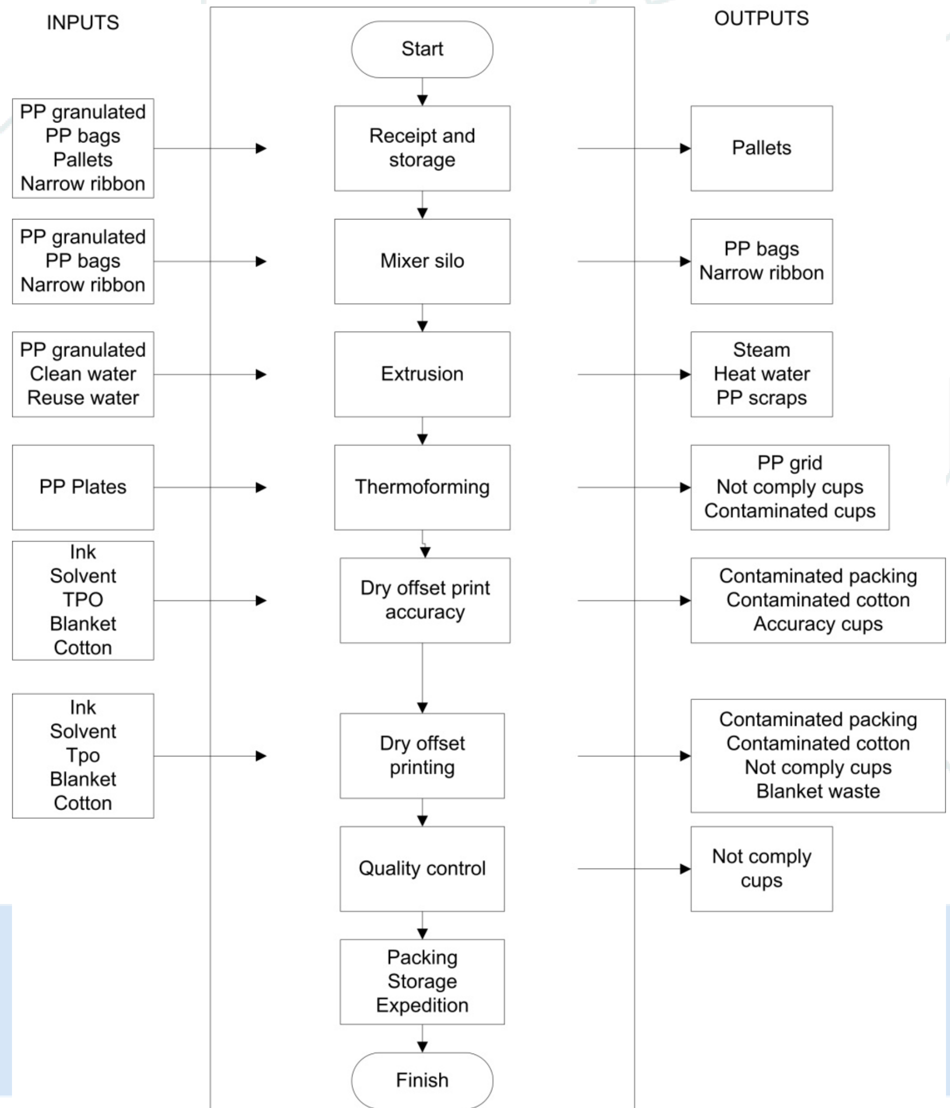


Fig 3. Flowchart of the process of production of packaging yogurt cups.

4. Application of EPIP tool in Case study

- 45 environmental aspects identified
- 1 in the receipt of stocks, 3 in the mixer silo, 4 in the extrusion, 1 in the water cooling, 4 in the Thermoforming, 1 in grind, 6 in the dry offset print setting, 7 in dry offset printing, 4 in cleaning, 6 in general purpose, 2 in kitchen, 3 in office, 1 in maintenance machines, and 2 in internal transportation.

4. Application of EPIP tool in Case study

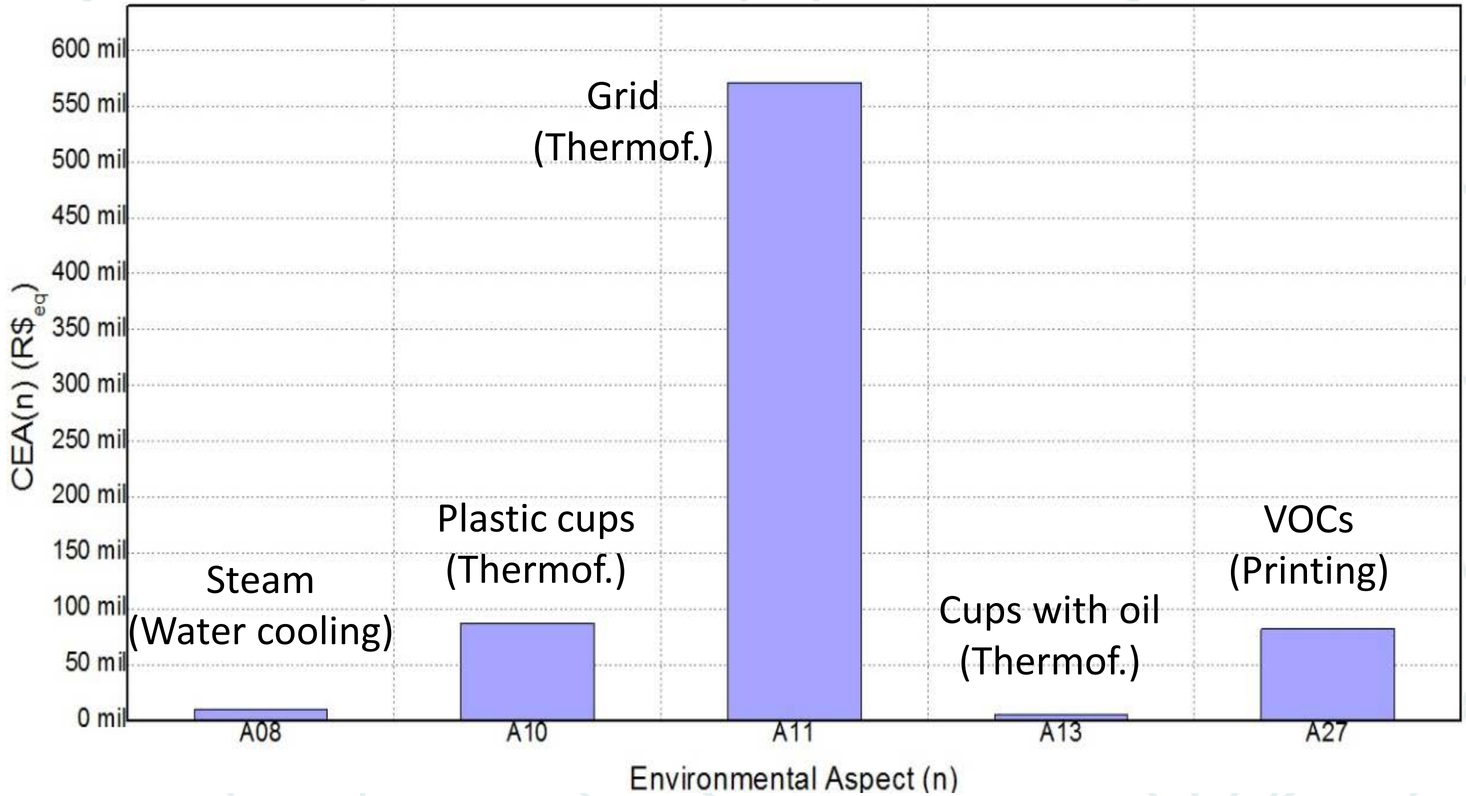


Fig. 4. Results obtained for the five environmental aspects larger equivalent costs by EPIP tool.

5. Conclusions

- EPIP tool has as main contribution to the state of art provides a decision-making support tool to evaluate environmental performance having a different approach than other existing analytical tools.
- The tool built in this study has an environmental and economic analysis integrated enabling the industry to analyze aggregated data of materials, energy, costs and environmental impacts, providing a result through a single score (Equivalent cost of environmental aspect, CEA(n)
- EPIP tool prioritizes the use of data with ease of control and collection by industries.
- The application of EPIP tool in a yogurt packaging cup industry demonstrated that it is a useful tool to aid in decision-making.
- Nevertheless, it is necessary to conduct more studies with different industrial typologies to check the outcomes from the EPIP tool for different situations. It is also important a review of normalization factors defined for aggregation of the impact categories

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THANKS A LOT AND BEST REGARDS!!!