123 The influence on LCA precision by data quality and data deficiency

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In this paper, a new LCA software tool (EMLCA), in which environmental load calculation, sensitivity analysis, uncertainty analysis and priority analysis are carried out, is introduced. The case study of copier is analyzed by EMLCA, the CO₂ emission and its uncertainty is calculated. The priority order of the uncertain data is identified, and the influence on LCA precision by data deficiency in the simplification is also studied.

Keywords: LCA; sensitivity; uncertainty; data deficiency; spreadsheet

Introduction

Many models were developed for Life Cycle Assessment (LCA) after it had been accepted as an effective tool for evaluating the environmental burdens associated with a product, process or activity all over the world. The methodologies for the environmental load calculation, sensitivity analysis and uncertainty analysis have been developed to a deep extent. However, there are still some problems when applying such models to LCA.

1. There are a large number of unit processes that make up a product system. It is unreasonable to expect all the processes and data with high accuracy, and there must be many neglected data and omitted data in LCA. The influence by data deficiency should be studied in the early phase of Life Cycle Inventory (LCI).

2. It is difficult to obtain the accurate data from the real product system. As many data used in LCI are uncertain, it is necessary to study data quality in order to assess the uncertainty of final environmental loads. Moreover, in most cases, it is necessary to determine the distribution of the input data before carrying out the model, but it is somewhat difficult and delicate.

In this study, a simplified and effective LCA software tool is developed, in which it is very convenient to calculate the environmental loads and to study the influence by data quality and data deficiency.

Developed system

Excel Management by LCA (EMLCA) is newly developed. It is a software tool that is intended to support the LCA procedure on the spreadsheets of Excel.

The structure of EMLCA is shown in Fig. 1. All the six parts of real line have been developed in EMLCA, and the parts of broken line will be developed in future. Each part is corresponding to one spreadsheet.

1. All the data can be inputted directly without identifying if they are necessary or not in inventory calculation. And the function unit that the different product alternatives are supposed to deliver is decided in this sheet.

2. The data, which imply the relation between unit processes, and the data, which indicate the environmental load in unit process, are identified. And the uncertain data’s mean value and standard deviation are also calculated.

3. The final environmental loads (consumed energy, used material, released waste, byproducts etc.) are calculated using matrix method. The environmental loads from each unit process are also listed in this sheet, which makes it easy to study the importance of each process and identify the key processes.

4. The environmental impact assessment is carried out using the results in the inventory phase.

5. The sensitivity analysis, which examines the intrinsic sensitivity of the system, is carried out using the perturbation method. All the sensitivity analysis results are listed in matrix, and the items in the sensitivity matrix indicate the changes of the results as a function of small fluctuations of the parameters.

6. The uncertainty analysis is carried out using the sensitivity analysis results. As there are a great number of unit processes in a product system and the input data are independent of each other, according to the central limit theorem, it can be affirmed that the final environmental loads are in normal distribution approximately.

All the calculation in EMLCA is fully based on matrix algebra and it can be seen as the coefficient matrix, its inverse matrix and the environmental load matrix etc. are all shown in the sheets. This also allows the employment of advanced computational techniques, such as analytical uncertainty analysis, key issue analysis etc.

The influence by data quality and data deficiency is also studied in EMLCA. First, according to the central limit theorem, the uncertainty analysis of the LCI results is carried out. Secondly, the uncertain data’s contributions to the LCI results and to the uncertainty are determined. Finally, according to the contributions, the priority order of the uncertain data is identified and the primary input data can be selected.

If the probability distributions of the input data have been determined, or at least the probability distributions of the primary input data have been determined, the Crystal Ball® which is a risk analysis software tool for decision making, can be connected to EMLCA to study the uncertainty of LCA results and to forecast the trend of environmental impact in future.

Case study of copier by EMLCA

The case study of copier is used to examine the performance of
EMLCA. The focus of this study lies on the CO2 emission of a copier in its life cycle. It is assumed that the input data are uncertain. Using the Crystal Ball software, we bring dispersion to the data with different distributions such as uniform distribution and normal distribution etc.

By EMLCA, the final CO2 emission is calculated and it is identified to be in normal distribution according to the central limit theorem. The contributions of the uncertain data to the CO2 emission and the contributions to the uncertainty are also determined. Here, the sensitivity value of a datum is considered as the indicator of the contribution to load, and the ratio of the variance of the datum to the variance of the final result is considered as the contribution to uncertainty. According to these indicators, the uncertain data are managed in logarithmic scale coordinates as shown in Fig. 2.

![Fig. 2. Prioritization of the uncertain data in the case study of copier](image)

In Fig. 2, both the contributions in the left lower corner are high and those in the right upper corner are low. Therefore, it is obvious that the data in the left lower corner are most important, whereas those in the right upper are less important. From the left lower to the right upper, Fig. 2 shows the priority order of the uncertain data. For example, the datum of a16, which is in the most left lower place, represents the CO2 output in the process of paper production. It means that this process is the key issue, and the datum of CO2 output cannot be deficient and its quality should be analyzed in depth in the following procedure. On the contrary, quality and deficiency of the data in the right upper place have little influence on the LCA results. From this figure, the primary input data can be identified and selected.

Since the data in the right upper corner in Fig. 2 are judged unimportant, five data in the corner are canceled to simplify the case study of copier. This simplified case is analyzed by EMLCA, the CO2 emission and its uncertainty are calculated again. The results before and after simplification are compared to study the influence on LCA precision by the data deficiency, as shown in Fig. 3.

![Fig. 3. Comparison of the CO2 emission results (1: the CO2 emission before simplification; 2: the CO2 emission after simplification)](image)

In Fig. 3., after the simplification, the mean value of CO2 emission is reduced by only 0.01%, and the standard deviation is not changed. So that it can be said that the LCI result is almost not changed after the simplification. The qualities of the data have quite few influences on the LCA precision, and these data even could be neglected from the LCA system.

Monte Carlo Simulation for LCA

In this paper, as the uncertainty of the input data is assumed, we can know the probability distribution of the uncertain data. Crystal Ball is used to perform the Monte Carlo simulation to the case study of copier for the uncertainty analysis. The CO2 emission result is shown in Fig. 4., from which its probability distribution can be known.

![Fig. 4. Probability distribution of CO2 emission analyzed by Crystal Ball](image)

Conclusions

EMLCA, which is a LCA software tool, is introduced in this paper. The methodology of LCA analysis in EMLCA is represented. Demonstrating EMLCA with the case study of copier, it is shown that EMLCA is sufficiently effective in calculating the environmental loads and studying the uncertainty propagated from the uncertain data. Using EMLCA, it is also very convenient to identify the priority order of uncertain data and to study the influence on LCA precision by data deficiency. The Crystal Ball software can be connected to EMLCA to study the uncertainty of LCA results and forecast the trend of environmental impact in future.

References

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