Combined assessment methods for decision support in product development

Eric Lutters, Marten E. Toxopeus, Fred J.A.M. van Houten

Laboratory of Design, Production & Management, Faculty of Engineering Technology
University of Twente, Enschede, The Netherlands

Abstract

In each stage of design and engineering processes myriad decisions are made, each influencing a large number of other processes. Often, these decisions are made implicit; if however, decision processes are more structured and transparent, a better support of product developers can be realised. In order to achieve this, also a more structured way to value different aspects in product development is required. Consequently, the assessment methods and the comparison of these methods require additional attention. Based on cost assessment, the corresponding working methods are shown. Additionally, these working methods are generalised for usage in other (life cycle) assessment methods.

Keywords:

Decision making, cost estimation, life cycle assessment methods

1. INTRODUCTION

In product development cycles, designers and engineers endeavour to reach adequate solutions for the problems they are confronted with, within the constraints and context imposed on the project. Not only is the foundation for decisions they have to take often incomplete; usually, the quality of the information content that underpins the decisions is undecided. This not only introduces uncertainty in product development cycles, it also arouses subjectivity.

This is especially true if life cycle aspects like safety, environmental impact and maintainability are involved. Standard Impact Assessment Methods (IAM's) are practical to determine the impacts on the different aspects. However, in everyday practice this is not ideal. As a simple example, in cost estimation, methods depend on the phase of the development cycle; moreover, different (exchangeable) cost functions entail different results in comparable situations. The same yields true for the wide range of environmental effects enforcing the necessity to use weighting factors to aggregate the different effects into a single indicator value, and each IAM will use different sets of weighting factors.

Consequently, in product development cycles, there is a clear need to improve the basis for design decisions. Especially for designers that are not specialists in the fields under consideration, it can be hard to make a well-founded choice for the IAM's to be used. As the applicability of analysis methods depends on the product type and the maturity of its description, different information is required regarding the different aspects. Therefore, designers must be supported in the appropriate use of impact indicators.

This publication provides a basis for the phase dependent comparison of life cycle analysis methods. In this, the quantity and type of analysis methods is very flexible. The publication firstly addresses the product development cycle and decision making processes in this cycle. Based on this, the description of what-if design and estimation methods in cost control lead to a generic description of working methods to concurrently employ assessment methods for decision support in product development.

2. DEVELOPMENT CYCLE

Added value in the supply chain is generated by executing the processes that together realise the entire product development process. It makes sense to discern two different types of product life cycles: the physical product life cycle (addressing instantiations of a certain product type), and the development product life cycle (addressing all aspects of design and engineering of the product type).

The latter is concerned with the development process that enables the sheer existence of the physical product life cycle. The development product life cycle determines the attainable added value for a product type, as much as it determines the costs that will incur during the production and rest of the physical product life cycle.

This leads to a discrepancy that is typical for all development processes: on the one hand, all possible consequences of decisions in development cycles should be taken into account; on the other hand, the efforts involved should not exceed the added value generated. The effectiveness and efficiency with which the design and engineering processes are carried out contribute considerably to the extent in which the product development process can be realised in a profitable manner. In increasingly complex manufacturing environments this evidently requires a very good overview of the entire development process, the resources involved and the planning of all processes. For humans, this overview is very hard to obtain and to retain. One way of achieving this overview, is to impose strict protocols on activities during the development cycle; this however leads to situations where design methods become straitjackets, or to environments where PDM and ERP systems conjointly hold sway over the company.

The reason for this loss of flexibility in development cycles is related to the fact that the execution and control of processes are not independent. This dependency can be addressed by focusing on the information content that underlies the decisions in the development process; additionally, the information content can be used as a way to govern development cycles [1].

3. DECISION MAKING IN PRODUCT DEVELOPMENT

During design and engineering phases of product development, numerous decisions are taken by the design teams. These decisions are concerned with extremely diverging topics, implying that either the design team or co-operating specialists are not only able to survey all aspects involved in the project, but also that they are able to weigh the consequences of all those decisions at any given moment.

In everyday practice, this may seem a clear infeasibility; nevertheless, design teams are able to cope with it because of their knowledge, experience and intuition −something that can not be grasped by any computer. This, however, does not imply that computers can not support design teams in their efforts to arrive at better solutions for the problems they encounter.

Almost every decision taken by a product developer seems to be independent and specific; yet, at closer inspection, the structure of almost all decision processes show considerable similarity. The differences that do exist are related to the information that is involved; either the type of information, the amount, reliability and completeness of information or the context of the information are different. Consequently, it may, in general, be possible to address all the decisions in the development cycle in a similar manner, by looking at the basics of the decision making processes in a different manner.

For representing the process of problem solving and decision making, the model presented in figure 1 is used. In this model, three main co-operating aspects play important roles. These aspects are 'problem solving', 'decision making' and 'evaluation' respectively. This subdivision facilitates the objectification of the overall decision making process; thus realising more transparent and reproducible steps in the development cycle.

Decision making is the cognitive process of prioritising and selecting a (set of) means from among multiple alternatives. In this, rationale and argumentation play an important role. It is a process where information and the decision maker's knowledge are literally decisive for the course of action which will be pursued. Decision making typically consists of two elements; criteria and decisions.

Criterion element

Criteria relate to targets, objectives, consequences and requirements, involving the translation of these aspects into operational terms. This implies that these terms are suitable to be employed in the evaluation of alternatives. The purpose of criteria is to classify and value the proposed alternatives. Criteria can either be qualitative with no numerical targets or quantitative with numerical targets. In the model, a criterion is initially qualitative; in the course of its use, it can be made quantitative by coupling it with a unit of account. Therefore, the criterion element has an extra element called 'unit' (see figure 1).

Decision element

A decision is an agreement on which alternative to use as the basis for further proceedings. Moreover, it is the final result of examining an issue with all attached aspects. A decision selects the (set of) means based on the evaluation of these alternatives. Although attention should never be distracted from the significance of reaching decisions whenever required, decisions can also be considered to be dynamic. The latter implies that decisions may be revisited later, as preferences, insights or conditions change or new alternatives are generated. As such, each decision (at least) consolidates a 'restore point' in development cycles, making the development process more transparent and aiding to obtain design histories. Much of the circumstances in later stages of product development can then be retraced to a set or sequence of decisions. This, together with an adequate management of the information content, obviously gives an improved basis for the development cycle.

3.1 Evaluation of alternatives

The processes that evaluate alternatives facilitate decision making by providing a structured analysis of the available alternatives. However, the practicability of such processes is limited, as individual preferences can play an eminent role. In most cases, decision makers have some intuitive (preconceived) notion on the preferred alternative. These preferences will be carried along the evaluation, either consciously or unconsciously. No structured evaluation method will change that. What is more, such methods can actually be abused to underpin an individual's preference.

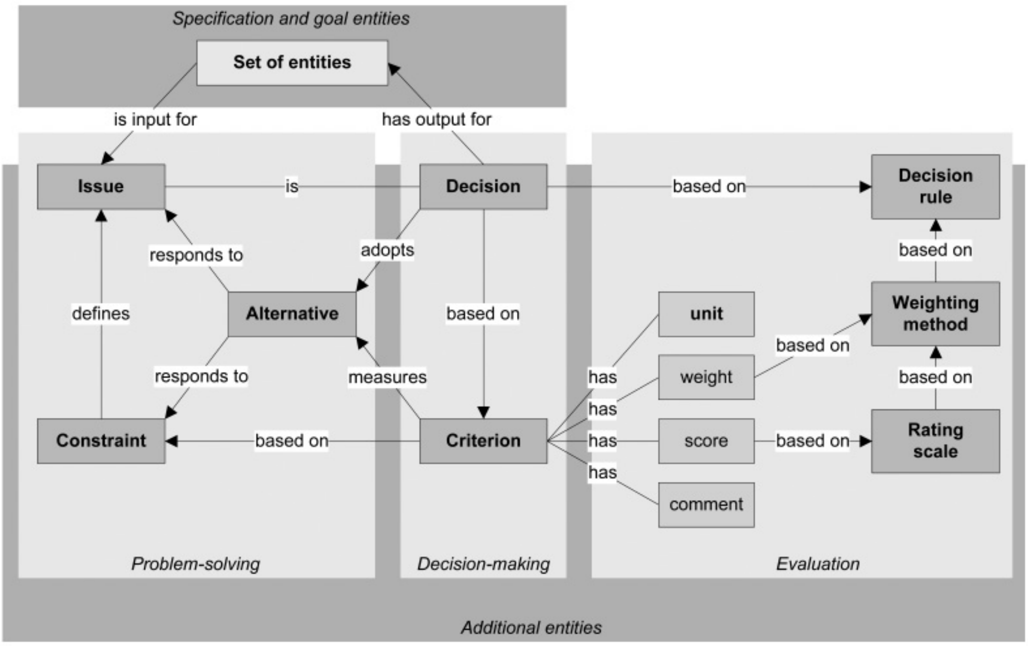

Figure 1: decision model

In structured evaluation processes, three elements play an important role. These are decision rules, weighting methods and rating scales respectively. However, the model (figure 1) leaves room for additional elements as well. For instance, risk might be a crucial factor in decision making. Each and every decision deals with lack of information and uncertainty of available information. These aspects increase the risk of making a decision that may later turn out to be wrong. The model provides the possibility of adding such elements to the evaluation process as instantiations of criteria.

3.2 Decision rules

Decision rules are used to determine the strategy in evaluating the alternatives. Based on the chosen decision rule, working methods to evaluate criteria and alternatives can be established. Together, these working methods realise the evolution of the information content that is required to make the decision.

An example of an obvious decision rule that might be applied is ‘choose the highest scoring alternative’. In principle this is not a bad rule, but in practice it may not work out, as it does not take into account the relative score of e.g. the alternatives with the highest and next highest score. If only a slight difference exists, additional analysis is required. Therefore, more elaborate decision rules should be considered. Some examples are:

- Compensatory rule: select the alternative with the highest total score. The total score is the sum of the scores per criterion multiplied by the weighting factor for that criterion;
- Conjunctive rule: determine the threshold for each criterion and select on basis of these thresholds;
- Disjunctive rule: rank the criteria and then determine the threshold for the highly ranked criteria; then, select on basis of these thresholds;
- Lexicographic rule: rank the criteria and select based on the comparing the most important criteria.

3.3 Weighting method

To assign importance or meaning to a criterion, often weighting factors are used. They make the decision process much more complicated; therefore, it is questionable whether these factors are useful under all circumstances [2]. In practical situations, using weighting factors is often just a ‘shift’ of the problem. However, they can be useful to express the overall value judgement on the criteria by all team members involved.

Obviously, there are some weighting factors are used to compare criteria, Obviously, common sense gives some guides on how to use weighting factors; e.g. one criterion should not overrule all the others. There is a clear risk that the sheer complexity of the decision making process enshrouds such logic; therefore, weighting factors can only be useful if employed in a strict, transparent and structured manner. In general, there are four methods to assign weights to criteria:

- Grading: assign a value to each criteria on basis of a pre-defined scale;
- Dividing: divide a pre-defined number of points over the different criteria;
- Ranking: rank criteria based on their importance;
- Multi-criteria: compare criteria pair by pair and identify the relative importance of each criterion.

Rating scales

Usually, each alternative is scored to each of the identified criteria. Rating scales enable this process. The following scales can be applied:

- Nominal: a scale for mutual exclusive, but not ordered, alternatives. This scale is used to determine whether an alternative is suitable or unsuitable;
- Ordinal: a measurement where the order matters but not the difference between values. It is used in determining which the better alternative is;
- Interval: a measurement where the difference between two values is indeed meaningful. As well as a rank order, also a degree of difference is given;
- Ratio: equal to the interval scale, but additionally has a clear definition of the origin.

The decision rule, weighting method and rating scale are three elements that are indispensable for the evaluation process. Each of these elements has at least four options, resulting in tens or even hundreds of possible options. There are of course some interdependencies among the elements. Applying a conjunctive rule, the weights of each criterion are less important compared to applying a compensatory rule. The latter selects the alternative with the highest weighted score. In such case it is more appropriate to use a multi-criteria analysis, then when applying a conjunctive decision rule. Therefore, it is possible to limit the options, although a rather large set of options remains; intentionally reducing the set even requires additional decision making.

3.4 pre-specification of evaluation method

As the selection of evaluation methods in decision processes should rather be based on strategic considerations than on everyday activities for individual decisions, the evaluation methods and their employment should be specified on beforehand. Especially the decision rule and weighting methods can be determined prior to entering a certain phase in the project. Issues addressed in specific phases are likely to display some similarities and can therefore use analogous evaluation methods. However, for rating scales, this is a bit more complicated. As the overall decision model supports the possibility to have both qualitative as well as quantitative criteria, the scales used for rating can hardly be determined on beforehand. The applied scale depends on the type of criteria, thus a qualitative criterion will automatically enforce a ratio rating scale to be used.

3.5 Level of aggregation

As an ‘issue’ (figure 1) in decision making may consist of sub-issues, or have entailing issues, the level of aggregation explicitly becomes important. Moreover, although an issue initiates a decision process, it can also stem from such a process. In other words, a decision element can serve as input entity for another decision process. In fact, there could be several aggregation levels within the decision model.

At first sight, this highly complicates the decision making process. However, in recognising that development cycles already encompass all such decisions, this cannot be the case. The reason for this ostensible complexity stems from the fact that these decisions and their level of aggregation can now be explicitly addressed. Although this results in a ‘web’ of interdependencies, an adequate information management system can provide an effective manner to represent all this information in a structured and transparent manner. Working methods like what-if design can than assist in effectively utilising the information content.

4. WHAT-IF DESIGN

In the above, a structured representation of decision processes is given; however, in real life there hardly is a possibility to map all decisions completely. The main reason for this, is that not all decisions are equally interesting or important. In other words, the vast majority of all decisions are quite routinely; requiring hardly any expert intervention. One of the goals of what-if design [3] is to facilitate designers in focusing themselves on the non-routinely problems.

It is difficult to give a precise definition of what-if design. The closest comparison is what goes on in the mind of a designer (or engineer): continuous deliberation on various solutions that lie ahead. The consequences of the different options are assessed; both for the product under development and for the corresponding processes. Many of these decisions are concerned with routine tasks, with the ever present danger of overlooking important details.

What-if design initially aims at supporting the designer in those routine tasks, by taking care of the larger part of the basic explorations, surveying and scrutinising the information content. Then, the team members can focus on what they do best: find creative solutions for the more challenging problems. In the meantime, the design support system registers design decisions and the context in which they were reached. Based on this, what-if design additionally focuses on a more elaborate ambition: the support of designers by actually raising solutions; either in automatic mode, or in interaction with the team members.

If what-if design techniques would be developed on a process oriented basis, it would be extremely hard -if not impossible- to find any sequence of processes leading to the desired goal; let alone that the manner in which the goal is pursued would be predictable. The only way to achieve this is to describe all possible combinations on beforehand. Setting aside the fact that this is a sheer impossibility, it would lead to an enormous loss of flexibility and transparency, moreover, it would create overwhelming overheads of rules, process descriptions and prescriptions for the employment of these processes. This situation is comparable to finding yourself in a maze, where all intersections look the same; but what is worse, experience will not help you, because this particular maze changes each time you enter it.

The situation becomes different if attempts are founded on an information based approach. In this case, the current status of the development project is already definite and known. Moreover, using an ontology [1], even the meaning of the information content is known and employable to govern the course of processes.

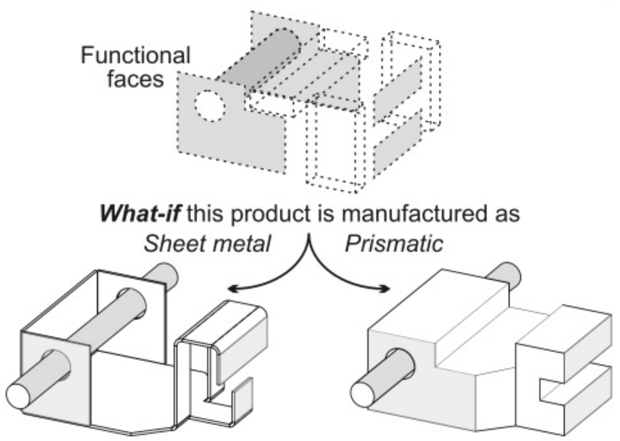

Figure 2: Overly simplified example of what-if design.

4.1 What-if design and information management

What-if design can be essentially be seen as a request for the controlled evolvement of the information content in a certain direction. More precisely: it hypothesises a certain status of the information content that deviates from the actual information content. From this, it uses workflow management techniques to govern processes. It continuously explicates decisions, and relates the corresponding issues, criteria, constraints, and alternatives to the information content. What-if design, therefore, attempts to reach logical decisions, in a logical sequence; thus both supporting the development process, and simultaneously contributing to the establishment of design histories. In what-if design, this is completely independent of the level of aggregation and the problem domain at hand. Moreover, what-if design can deal with subjective representations of the information content; thus it allows for contemplations on, and compromising between different interpretations, but also for different methods and properties for the same issue, throughout the entire development life cycle.

5. COST ASSESSMENT IN PRODUCT DEVELOPMENT

A clear example of the use of different methods and properties is available in regarding the assessment of cost in product development; the number of possible approaches is massive. Moreover, different team members from different backgrounds will probably be convinced that 'their' approach is the only one that makes sense. Yet, there has to be one overall (accepted) estimation of the product cost available, in order to make sensible decisions on more strategic levels. Effective cost control requires information that covers the entire product development cycle. This information is generated and affected by different engineering tasks such as design, process planning and production planning. Since all the information required for cost control is not always available at the desired time, historic information is also of major importance.

The task of cost control is twofold. On the one hand, it has to detect cost values and the sources of these costs. Therefore, it can initiate a well-founded product modification in order to keep costs within a predetermined range or to cut costs in general. On the other hand, it has to compare cost estimates with the actual costs. In this way, cost models can be improved. The feedback of cost information is an essential part of cost control.

Decisions taken during engineering tasks are based on a diversity of information (see also figure 3). Usually, the decisions are concerned with different engineering objects and usually the available information differs in detail, completeness and reliability. Through engineering tasks analysis, it can be concluded that decisions made during different engineering tasks influence each other. Furthermore, engineering tasks use information from and/or generate information for other engineering tasks. In order to tune the need for and the availability of information from different engineering tasks, the structuring of information has to be unified and communication between the engineering tasks facilitated. Therefore, for the integration of engineering tasks in the product development cycle an information management system is indispensable.

In cost estimation two distinct cost estimation methods exist, generative cost estimation and variant based cost estimation. Both methods can be applied simultaneously to one product, resulting in a hybrid cost estimation method.

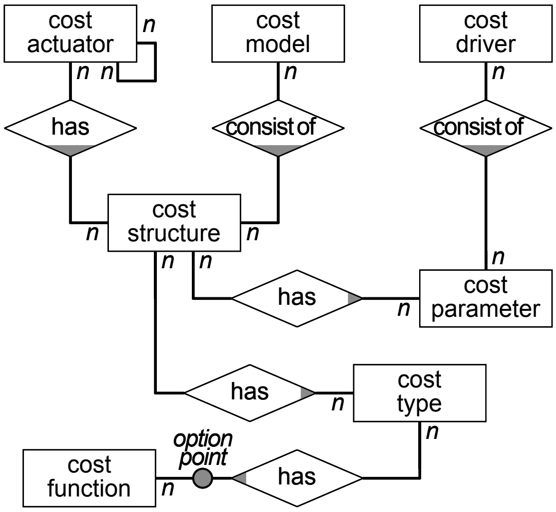

Figure 3: information structure for cost estimation.

5.1 Variant cost estimation

Variant based cost estimation assumes that geometrically similar products are manufactured with the comparable production processes. Consequently, it is necessary to compare a new product with previously manufactured products. The actualised costs of historical products that show a certain degree of similarity can be used to generate a cost estimate, i.e. the average costs of these products. It is clear that adequate historical information is essential.

Furthermore, the best opportunity to apply variant based cost estimation is in small and medium batch manufacturing of relatively standard products. Because no additional information has to be generated for the cost estimation process, it is a relatively quick method and very useful in the early product development phases.

5.2 Generative cost estimation

Generative cost estimation is based on the fact that the cost of a product depends on the required processes and materials. By determining the required manufacturing operations and materials and the extent in which these are used, it is possible to generate a cost estimate. Furthermore, the overhead costs have to be added proportionally. This method is obviously closely related to process planning. In general, generative cost estimation generates a detailed and accurate cost estimate, however, a considerable disadvantage is the fact that it requires much detailed information. The generation of this information is usually very labour intensive and time consuming. Generative cost estimation is applicable in small batch high variety manufacturing to large batch manufacturing.

5.3 hybrid cost estimation

Both variant based and generative cost estimation can be applied at the same time for one product, resulting in a hybrid cost estimation. In the development cycle of products, it can occur that parts or modules of a product will be in a different phase of the product development cycle. Therefore, the available information of distinct parts of the product will be dissimilar. When the costs of different parts of a product are calculated in a different way, the total product costs can be calculated by summing the costs for these parts. When different cost models are used, a prerequisite is that the calculation of the overhead costs is carried out in the same way. If the overhead costs are calculated in a different way, it can occur that some overhead costs are counted more than once or that some overhead costs are excluded. In order to ensure consequent calculation of overhead costs, an aggregated product information structure and cost structure is required. Only in that case, it is possible to store the way the overhead costs are calculated and on which aggregation level the overhead costs are calculated.

Aggregation in decision making

Based on the information management approach [1], it is possible to combine different ways of cost calculation, independent of the level of aggregation. In this, a very flexible and generic way of working becomes available, where design support systems can autonomously prepare huge amounts of information. This enables development teams to quickly and efficiently get (aggregate) overviews and assessments of information, without much effort. Risk- and sensitivity analysis can be treated alike.

The use of the information content, together with the ontology makes this manner of design(er) support wellnigh independent of the application domain. In other words, the proposed working method for cost estimation can easily be applied in other domains, e.g. to effectively and efficiently realise decision support for assessment methods.

7. ASSESSMENT METHODS: DECISION SUPPORT

The scope, boundaries and level of detail of e.g. an LCA study depend on the subject, and intended use of the study (see [4-7]). The depth and breadth of LCA studies may differ considerably, depending on the goal of a particular LCA study. As LCA is one of several environmental management techniques (risk assessment, environmental performance evaluation, environmental auditing and environmental impact assessment etc.), it is not -by definition- the most appropriate technique to use in all situations. It e.g. typically does not address economic or social aspects of a product.

The nature of choices and assumptions made in LCA (and other environmental management techniques) like system boundary settings, selection of data sources and impact assessment methods may be subjective. Additionally, a considerable number of other, subjective, assumptions have to be made, e.g. on especially the life cycle phases of which is even less known and that are hard to predict, like the use phase and the disposal phase. Product developers can try to influence and direct these phases by making certain decision during the development of the product. Of course this uncertainty strongly depends on the type of project. During the development of a complete new type of product (e.g. the first series of CD players), the usage and the disposal phase are very difficult to predict, as is the actual life span of the product. On the other hand, during the redesign of familiar and well-known products, developers can employ historical information on typical usage or disposal. Obviously, this is strongly related to the methods for cost assessment as described in section 5.

Generally, the information developed in an assessment study should be used as a part of a much more comprehensive decision process or used to understand the broad or general trade-offs. Comparing results of different LCA studies is only possible if the assumptions and context of each study are the same. These assumptions should also be explicitly stated for reasons of transparency. This is absolutely true and consequential in using different assessment methods for one product. Therefore, it almost seems impossible to compare the results of different assessment methods. This is supported in recognising that there is no scientific basis for reducing LCA results to a single overall score or numbers since trade-offs and complexities exist for the systems analysed at different stages of their life cycle.

However, in recognising that in general decision making in development cycles usually different alternatives are compared, this situation changes considerably. After all, in development cycles there is no comparison of assessment methods required, but a comparison of alternatives that may be characterised by several, dissimilar, and possible incompatible assessment results. In that case, the assessment methods themselves need not be compared, but they become different criteria in the decision making process. As shown in section 3.3, structured and transparent ways to deal with multiple criteria in decision making are available.

7.1 Efficiency and effectiveness

Assessment methods usually require a lot of work, e.g. in preparation, data collection and data analysis; therefore, it usually is nonsensical to perform more than one type of IAM applied within the LCA. Although the results of multiple assessments would probably improve the accuracy with which decisions are reached (thus improving the product quality and the development cycle as a whole), the effort required to do this, virtually never can counterbalance this. This also indicates why it is extremely laborious to perform adequate sensitivity analyses, and why these sensitivity analyses are often reduced to less more than instinctive feelings. This, however, is a rather paradoxical situation, as the availability of different assessments could improve the quality of sensitivity analyses considerably.

As a result, the choice of assessment method(s) and the depth and breadth with which these are performed is usually limited by the amount of effort required. In everyday practice, this is often a missed opportunity, especially because the effort is constituted for the larger part of sheer donkey-work and routinely activities. The proposed decision model from section 3, combined with the what-if design approach depicted in section 4 provide an excellent opportunity to combine a multitude of assessments, without much additional effort. In this, the assessment methods can have varying scopes, at different levels of aggregation; additionally it is unimportant whether they are compatible, and if they are based on approaches that use weighting factors, or have a more deducible background [8].

In what-if analysis, much of the routinely activities can be performed in an almost autonomic mode, provided that a sound underlying information model is available (figure 3 shows such a model for cost estimation). Such a model needs to cater for adjustable use (e.g. by changing the cost function), and thus must be capable of incorporating different assessment methods etc. If such a model is available, what-if design can be used to ‘accompany’ the development cycle and its decision making processes with up-to-date information on life cycle aspects and sensitivity analyses thereof. As nearly all corresponding effort (e.g. data acquisition, data analysis and calculations) can be performed in the background, team members can readily have adequate support in decision making at their disposition. Comparable to the situation for cost assessment, here the origin of information can be of a variant based, generative or hybrid nature; thus speeding up the process of getting assessment information to the team members, but also adapting the type of the assessment(s) used to the stage of the development process. Not only can the information be available much quicker, it can also add more value, as different assessment methods can conjointly contribute to the decision making process. As deduced from the decision model, different criteria (i.e. assessments) can be considered in one decision.

As a first step towards an integrated autonomous system based on the what-if approach, a software tool that systematically calculates the outcomes of multiple IAM’s can be developed. The effort for modelling all alternatives under investigation will be identical, whereas the amount of resulting data will increase considerably. To prevent unmanageable quantities of data, the described methods (e.g. 3.3.) transform the data into structured categories, which are used as (scored) criteriain decision processes. First generation LCA software programs like Simapro [9] or second generation programs like Gabi [10] or LCAit [11] can be used to model the product life cycles and the necessary calculations to create the input for this proposed software tool. The software tool must be able to import and export data to and from those programs but also give direct (calculation) commands to these underlying programs.

8. CONCLUDING REMARKS

Decision making is one of the main underlying drivers of development processes. The way in which decisions are dealt with is strongly dependent on the situation, but as a general rule, the quality of decisions increases with the amount, but mainly the quality of the information on which they are based. This is made credible for cost estimation; however, as the used approach is generic, it can be employed for other assessment methods as well.

Combining the working methods for decision making, what-if design and analysis methods for life cycle aspects, allows product developers to adequately use an abundance of background information to buttress their decisions, without requiring additional effort. In future research, the way this can be applied in industrial practice will be studied in a number of case studies, elaborating the ideas and gaining experience to validate the working methods.

9. REFERENCES

[1] Lutters, D.; Manufacturing integration based on information management; PhD. Thesis; University of Twente; 2001.

[2] Boer, S.J. de; Decision Methods and Techniques in Methodical Engineering Design; PhD Thesis; University of Twente; Enschede; 1989.

[3] Lutters, D., Vaneker, T.H.J., Houten, F.J.A.M. van; ‘What-if’ design: a synthesis method in the design; In: Annals of the CIRP 53/1: 2004; p.113-116.

[4] ISO14040; Environmental management -life cycle assessment- principles and framework; 1997.

[5] ISO14041; Environmental management -life cycle assessment- goal and scope definition and inventory analysis; 1998.

[6] ISO14042; Environmental management -life cycle assessment- life cycle impact assessment; 2000.

[7] ISO14043; Environmental management -life cycle assessment- life cycle interpretation; 2000.

[8] Toxopeus, M.E., Lutters, D., Houten, F.J.A.M. van; Environmental Indicators & Engineering: an alternative for weighting factors, Proceedings of LCE2006, Leuven; 2006.

[9] SimaPro 6 LCA software; PRé Consultants bv, Amersfoort, The Netherlands

[10] Gabi 4; PE Europe GmbH, Leinfelden-Echterdingen, Germany

[11] LCAit; VD CIT Ekologik AB, Göteborg, Sweden.