INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN
ICED 05 MELBOURNE, AUGUST 15-18, 2005

IMPACT OF RESEARCH IN ENGINEERING DESIGN ON INDUSTRIAL INNOVATION

LARS HEIN

Keywords: Metrics, Indicators, Industry, Innovation, Engineering Design

1 Introduction

As performance evaluation is being imposed on universities worldwide, metrics for the effectiveness in both education and research are being developed and implemented. At the same time, many universities add a new dimension to their objectives: That they shall have a positive impact on innovation in industry. At the present there is only a limited understanding of the quantitative nature of 'university induced industry innovation', and a strict metric is not available at the moment. As funds for the universities are getting scarce, there is increasing focus on those, and only those, activities that show up results in the university evaluation. Consequently, individuals and groups are reluctant to involve themselves in industrial innovation, as results generated in this domain do not show up in an evaluation. In previous research [2] it has been demonstrated how design-oriented indicators are identified and set up. This paper examines the complexity of a comprehensive and complex metrics for the effects of engineering design research on industrial innovation.

1.1 Objectives

The objective of the research is to examine the qualitative and quantitative aspects of how engineering design research and the subsequent dissemination of derived design tools may support industrial innovation.

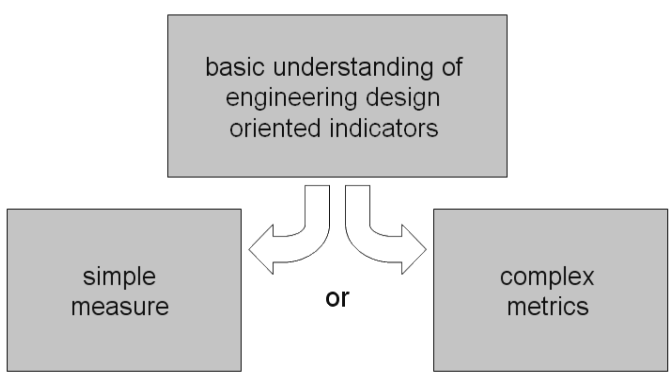

Figure 1. Even if a complete metric cannot yet be arrived at, a simple measure being a first approximation may be suggested.

Furthermore, the objective of the current work is to establish a metric for university induced industrial innovation, by which the impact of an individual, a group, a department or a university may be measured. Even if a complete metric cannot yet be arrived at, a simple measure being a first approximation is suggested.

1.2 Methods

Based on experience with a board spectrum of mechanisms for university / industry interaction, a basic model of the process that takes results of engineering design research through to impact the company (and ultimately to impact society), is suggested. From this process model, a simple measurement pattern is suggested. The complexity of the corresponding metrics for the effects of engineering design research on industrial innovation is then examined. From this it is demonstrated that benefits to the company and benefits to society from research in engineering design is influenced by overriding company internal and company external factors. Focus is then being put on the narrower, but measurable impact from research in engineering design on the design process in the company.

2 Impact from Engineering Design Research

The current understanding that research in engineering design is undertaken for the purpose of generating benefits for society and for industry suggests a simple model for the trickle-down effect. The model need to branch out in the last stage, because of the difference between what is good for business and what is good for society: the one is often, but not always, part of the other. By examining the different steps in the process it is evident that engineering design plays a crucial part in both of the end results, but on the other hand that other factors influences and often override in the process.

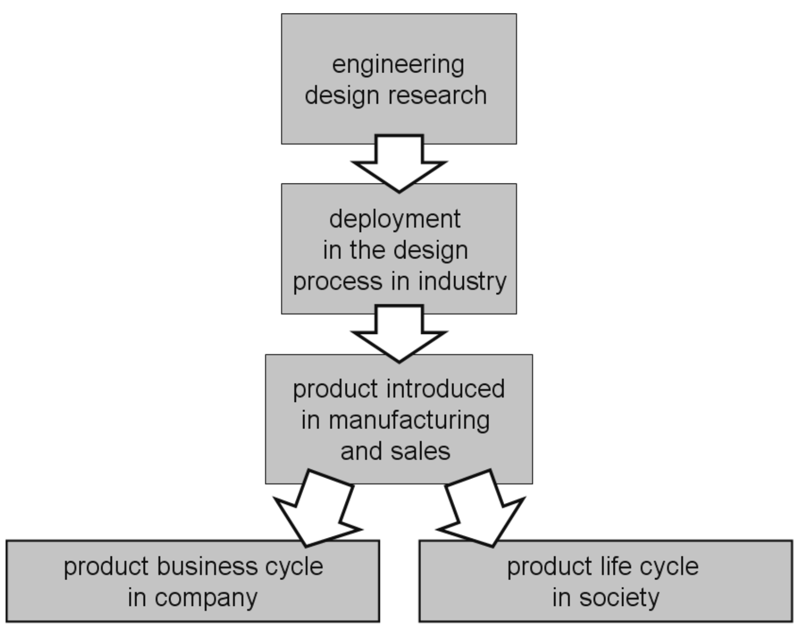

Figure 2. A basic model of the process that takes the results of engineering design research through to impact the company, and ultimately to impact society.

2.1 From research to the design process

Engineering design research gets to be operational and to be deployed in industrial innovation through a number of means. Experience shows that three basic mechanisms account for most of the transfer from academia to industry (figure 3) in the domain of engineering design.

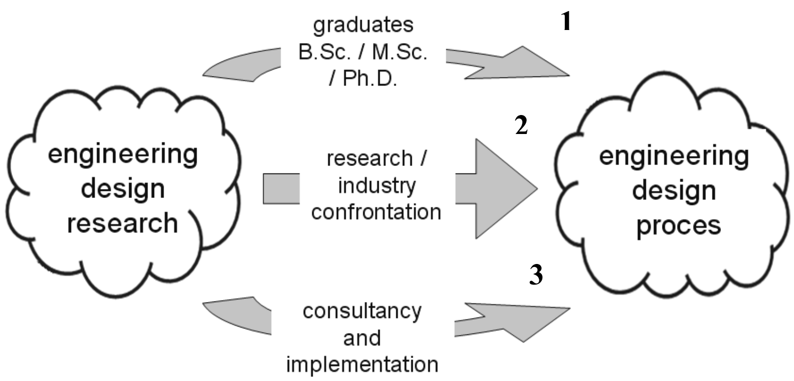

Figure 3. The three basic mechanisms which accounts for most of the transfer from academia to industry in the domain of engineering design.

Measurement of the first of these mechanisms are normally taken care of through the count of students that passes the examinations, and measured in CAT, ECTS, or otherwise. The third mechanism also often has its own measuring system, comparatively easy dealt with, in economic terms.

2.2 From the design process to the manufacturing and sales process

It has been demonstrated ([6], [2], [10], [13]) that by determining the product characteristics, the engineering design process heavily influences the conditions for the other processes in the company. However, even if an optimal design is arrived at, the (lack of) capabilities of the different departments responsible for the different processes may override the effect of the design.

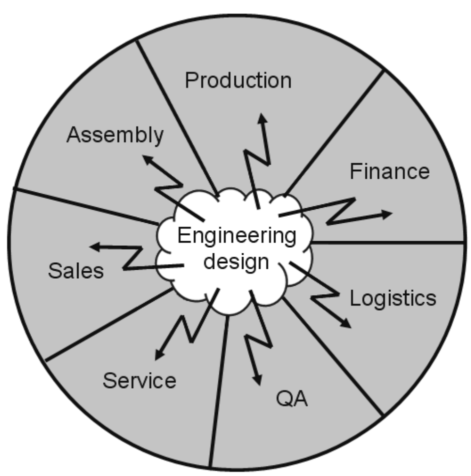

Figure 4. Through determining the product characteristics, the engineering design process heavily influences the conditions for the other processes in the company (adapted from [13]).

2.3 Benefits to the company

The benefits to the company of introducing a new product, i.e. the outcome of the product business cycle, is of cause governed to a large extend by the capabilities of the manufacturing and sales processes of the company, and thus influenced also by the engineering design process. However, a number of factors in the company's environment may override the qualities of the design process and of the business processes (factor set A).

- *Current level of customers confidence*
- *Current phase of long or short waves in economic conditions*
- *Barriers imposed by legislation*
- *Competition from other companies*
- *Product substitution*

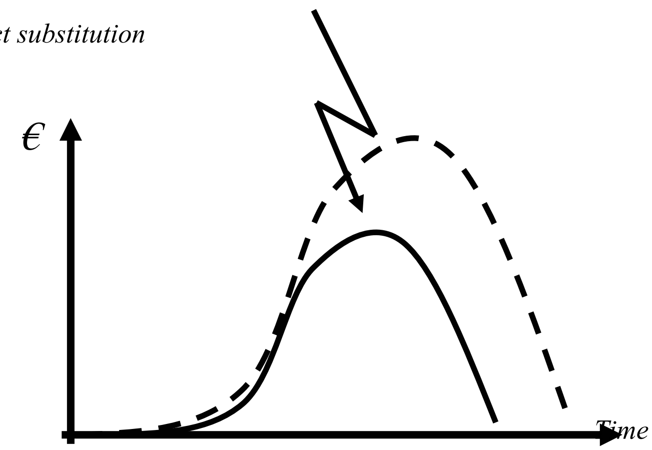

Figure 5. Factors in the company's environment may reduce the benefits below the potential (factor set A).

2.4 Benefits to society

The benefits to society of having access to a new product, i.e. the outcome of the product life cycle, is of cause governed by the characteristics of the product (or Product Service System), and thus influenced also by the engineering design process. However, a number of factors in the environment may override the qualities of the design, example (factor set B):

- *Failing product acceptance by customers*
- *Unintended use, and thus unintended consequences from, the product*
- *Incomplete service systems to support product*
- *Product life cycle deviating from the intended path*
- *Harmful impact from product or product processes on emerging systems, or vice versa*

Attempts in current design and engineering design education to introduce socio-technical disciplines may be seen as an effort to heighten the likelihood of the product actually meeting the expectations, by making the product or product service system robust towards harmful factors in the enviroment.

3 Measuring the impact of research in engineering design

A metric for the impact of research in engineering design may be applied at a number of different stages in the process.

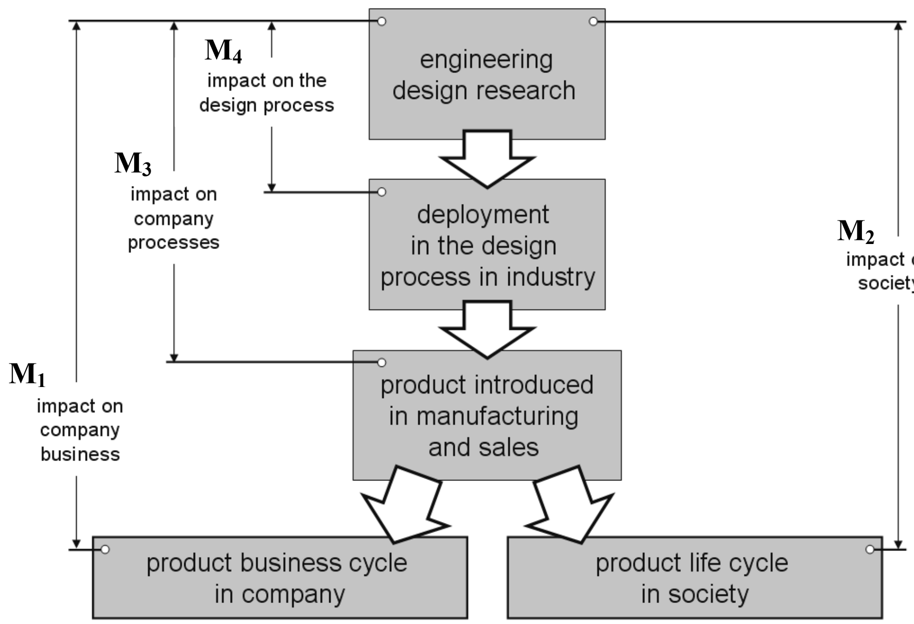

Figure 6. Different measurements of the impact of research in engineering design.

From the previous discussion of the nature of the various stages it seem evident that a metric by which to measure the impact of research in engineering design on either company business or society benefits must incorporate factors of which researchers have no control whatsoever

Impact on company business:

$$M_1 = f(\text{ED research, company processes, external factor set A})$$

Impact on society:

$$M_2 = f(\text{ED research, company processes, external factor set B})$$

Measuring on the level of impact on the company internal processes of manufacturing and sales makes for a much more controlled, and indeed a very relevant, metric, but still with elements which are beyond influence from the researcher

$$M_3 = f(\text{ED research, company processes})$$

Measuring on the level of impact on the engineering design processes

$$M_4 = f(\text{ED research})$$

may still be fraught with uncontrollable factors, but however less so.

4 From Design Research to Industrial Innovation

The production of graduates, and the consultancy and implementation activities, is already measured on a regular basis in most universities. However, a measurement of research / industry confrontation seems to be absent in most universities. As this is an important way of generating impact, a true and fair measure of this would be valuable.

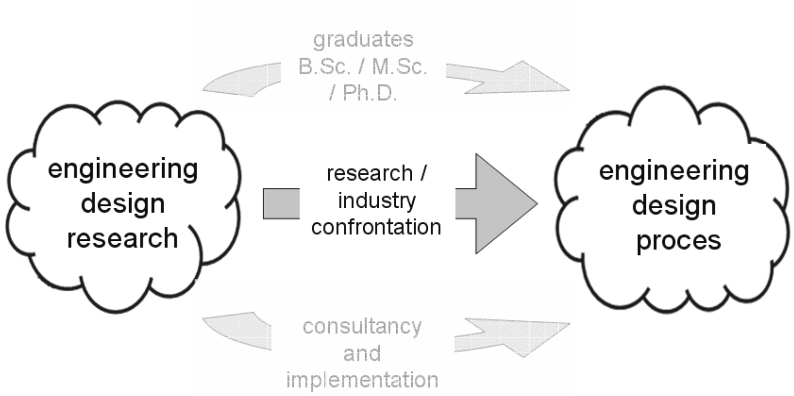

Figure 7. The research / industry confrontation is an important way of generating impact, and is still not measured on a regular basis in most universities.

4.1 Carriers of confrontation

Carriers of such research / industry confrontation may be of diverse nature, covering as some of the more important elements the following. Examples are from the Technical University of Denmark, Department of Mechanical Engineering, MEK:

- *Workshops and seminars (Product Development Methodology, Mechatronics Design, ...)*
- *Company specific, in-house courses (On quality, systematic design, design of mechanisms, Integrated Product Development, DFA, DFM, DFEn, ...)*
- *Hands-on design and development projects (design of components, sub-systems, or whole products, either through just a single step, or the whole, of the development process)*
- *Design project facilitation (advise on procedure, methods & tools, creativity, organization, design review, ...)*
- *Advisory to company management (diagnosis on design and development ability, benchmarking, reorganization of design and development department, strategic use of design tools, ...)*

Ultimately, a detailed metric based on these carriers may be worked out. At the present, however, only a simple measure is suggested, as a first approximation.

4.2 Common parameters for carriers of confrontation

The carriers of confrontation as suggested by the list in 4.1 do share a number of common parameters which could be made the basis of a simple measuring system. Of these, ***time spend in confrontation*** seem to be a simple, yet powerful parameter by which to measure.

Firstly, time spend in confrontation work both ways, influencing and impacting not only the engineering designer in the company, but also the engineering design researcher.

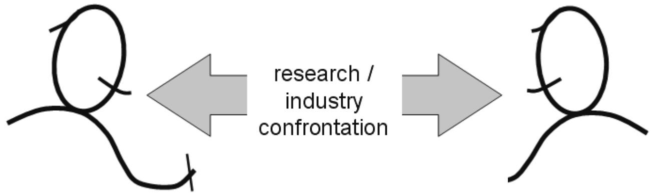

Figure 8. Time spend in confrontation work both ways, influencing and impacting not only the engineering designer in the company, but also the engineering design researcher.

Secondly, confrontation offers up a much more comprehensive set of means by which to convey and express the messages, than for example the written word, and it offers the option of dialogue, which will bring the discussion to the core of the issues in a way that writing and reading never will.

Thirdly, confrontation when conducted successfully lends credibility to the message from the researcher, as by the confrontation he offers his messages and opinions up for criticism and examination.

Lastly, confrontation requires mutual consent, thus bringing to a close any happening which is not beneficial to both parties. In this way the researcher will only be able to uphold confrontation over a prolonged career if what he offers is acknowledged to be of walue to industry.

4.3 A balanced metric for education, research and innovation

A metric for innovation will have to sit alongside the metrics for education and research, and thus it seems proper to do some kind of comparison between the tree metrics.

Table 1. A balanced metric for education, research and innovation.

Domain	***Carrier***	***Measure***
Education	Students	number of students **x** course points (CAT, ECTS, …)
Research	Publications	number of publications / citations
Innovation	Industry confrontation	number of man-hours spend in confrontation

A quick comparison seem to indicate that

- not one of the individual metrics are exactly fair on its own
- each of the metrics are ‘true’ to some extend
- each of the metrics are more accurate locally than globally
- each of the metrics reflects an acknowledgement by the receiving party
- each of the metrics may be detailed further (as is indeed already the case for education and research)

5 Conclusion

It seems evident that the ability to measure university induced industrial innovation is a prerequisite for the application of resources and funding in a lean university environment, thus the current need for a metric.

As design activities determine the ‘fate’ of most of the other operations (stakeholders) in the company, the impact may be greater (for better or for worse) than suggested by the indicated metric. The understanding of precisely how the design activities influence the stakeholders should be incorporated in the framework for future optimization of the measurement system.

The ultimate objective of the current research is to establish a complete metric for university induced industrial innovation, by which the impact of an individual, a group, a department or a university may be measured, to balance the existing metrics for the effectiveness in education and research that most universities have already implemented.

At the moment, however, a simple metric, ***time spend in confrontation***, is suggested as a simple yet powerful parameter by which to measure the impact of research in engineering design on industrial innovation.

References

[1] Branstetter L “Is Academic Science Driving a Surge in Industrial Innovation?” Center for Economic Institutions at the the Institution of Economics Research of Hitotsubashi University, Japan. Seminar June 2004

[2] Hein L “The Role of Design in University Induced Industrial Innovation”. In: Marjanovic, D. (ed.), Proceedings of the DESIGN 2004, 8th International Design Conference. Dubrovnik, Croatia 17-21 May 2004. pp. 267-272.

[3] Mowery DC, Nelson RR, Sampat BN, Ziedonis AA “Ivory Tower and Industrial Innovation“. Stanford University Press, ISBN: 0-8047-4920-5. November 2004, pp. 241 - 246

[4] Arenberg C (Ed) “The Impact of Academic Research on Industrial Performance”, The National Academies Press, Washington D.C., USA, 2003

[5] Bougrain F, Haudeville B “Innovation, collaboration and SMEs internal research capacities“ Research Policy, Volume 31, Issue 5, July 2002, pp. 735-747.

[6] Cantamessa, M, Duffy A, Hein L, Rimmer D “The Relationship Between Design Co-ordination, Design Performance, New Product Development and Strategy”. ICED99, Munich. Proceedings of 11th International Conference on Engineering Design, Heurista, Zürich 1999.

[7] Korhonen P, Tainio R, Wallenius J “Value Efficiency Analysis of Academic Research”, Interim Report, IR-98-032/June, IIASA, International Institute for Applied Systems Analysis, Austria 1998.

[8] Hein L “Design Methodology in Practice”. Journal of Engineering Design, Vol. 5, No. 2, 1994, pp 165- 181,

[9] Rosenberg N, Nelson R, “The Roles of Universities in the Advance of Industrial Technology”, Research Policy 23, Stanford University, USA, 1994.

[10] Olesen J "Concurrent Development in Manufacturing – based on dispositional mechanisms". PhD dissertation, Technical University of Denmark, Dept. of Engineering design (IK), 1992.

[11] Hein L "Product Development Consultancy". International Conference on Engineering Design (ICED91), Zürich (CH), August 1991, Serie WDK 20, Proceedings of ICED'91. Heurista, Zürich 1991.

[12] Mansfield E "Academic research and industrial innovation", Research Policy, Elsevier, vol. 20(1), 1991, pages 1-12.

[13] Hein L "Product Development Management and Time Compression". Chapter 46 (13 pages) of "Handbook of Industrial Engineering" (2nd Ed.), WILEY INTERSCIENCE, New York 1991, pp 1207 - 1219

Lars Hein, professor
Technical University of Denmark, DTU
Department of Mechanical Engineering, MEK
Section of Engineering Design
Nils Koppels Allé, Building 404
DK-2800 Kgs. Lyngby, Denmark
Phone: +45 45932522
Fax: +45 45932529
E-mail: LH@MEK.DTU.DK