Towards Integrated Product and Package Development

Bramklev, Caroline

2007

LUND UNIVERSITY

PO Box 117
221 00 Lund
+46 46-222 00 00

Towards Integrated Product and Package Development

Caroline Bramklev

LUND UNIVERSITY

Akademisk avhandling/Doctoral Thesis

Akademisk avhandling för avläggande av teknologie doktorsexamen vid tekniska fakulteten vid Lunds universitet som kommer att offentligen försvaras fredagen den 14 december 2007, kl. 13.15 i Kårhusets hörsal, Kårhuset, John Ericssons väg 4, Lund.
Fakultetsopponent: Prof. Sandor Vajna, Otto-von-Guericke-Universität Magdeburg, Tyskland

Academic thesis, which by due permission of the Faculty of Engineering at Lund University, will be publicly defended on Friday 14th of December, at 1.15 p.m. in Kårhusets hörsal, Kårhuset, John Ericssons väg 4, Lund, for the degree of Doctor of Philosophy in Engineering.
Faculty opponent: Prof. Sandor Vajna, Otto-von-Guericke-Universität Magdeburg, Germany

Towards Integrated Product and Package Development

Doctoral dissertation in Packaging Logistics.
Department of Design Sciences, Faculty of Engineering, Lund University, Sweden.

ISBN 978-91-976278-7-0
Media-Tryck, Lund, Printed in Sweden.

In memory of my father:
"…in the quest of getting this far…and further!"

Acknowledgements

"...I have the body of a weak and feeble woman, but I have the heart and stomach of a king…" (Elisabeth I)

There is a saying: "No man is an island". Neither is this woman!

There are numerous people to whom I would like to express my gratitude and thanks for their support, inspiration and contribution in the writing of this thesis.

First of all, I would like to thank my two supervisors: Professor Gunilla Jönson, for her belief in me, and therefore also warm-hearted and financial support of this project; and Professor Robert Bjärnemo, for generously sharing his knowledge in product development and his painstaking support during this journey.

I would also like to acknowledge the munificent support given by all the companies who participated in my research and, over the years, the continuous discussions provided. I am also most grateful to SCA Packaging Ltd. and Bo Rydin Foundation for their financial support of this project.

Furthermore, I would like to express my warmest appreciation of the help provided by my fellow researchers at the Department of Mechanical Engineering, Technical University of Denmark. Particular thanks go to Professor Mogens M. Andreasen for his intellectually stimulating contributions during the writing of this thesis, and to Assoc. Professor Claus T. Hansen for providing fruitful discussions on Integrated Product and Package Design. I am looking forward to continuing these discussions!

I would also like to give some special acknowledgement to: Karin Dahmström, Stockholm University, for kindly giving me suggestions for my questionnaire design; Anders Granberg and Magnus Lagnevik, Lund University, for knowledgeable advice on literature; Anders Ljungberg, Trivector, for advising me on process mapping; Professor Bodil Jönson, Lund University, for sound discussions on my draft manuscript; Henrik Glimstedt, Stockholm School of Economics, for his stimulating "train discussions" and kind encouragement when most needed.

I would also like to express my gratitude for the valuable guidance kindly provided by the Swedish Survey Institute, especially at the summer school in Tällberg, Dalarna, in 2003; and to my colleagues within the Design Society for all helpful discussions and tips provided over the years.

To my colleagues at the division of Packaging Logistics in Lund – thank you all for your cheerful spirits, kind advice and valuable support when I most needed it. I look forward to working more with you in the future!

I also want to thank Erik Andersson for administrative assistance, and Richard and Ulla Fisher for their swift and kind help in solving puzzles posed by the English language.

To my friends and family: This is it, I promise – this is REALLY it! Despite the ordeal(s) we have been through in recent years I cherish your endless support. To Patrik: *"Omnia vincit Amor!"* We have now come this far… and further… we will discover! I am so happy to be on that quest with you!

All remaining mistakes are mine alone.

Caroline Bramklev

Uppsala, November 2007.

Abstract

The following text is an abstract of this thesis.

The global company operates from a number of locations worldwide, resulting in implications for the transport, handling and storage of product and parts transported within the company as well as between the company divisions and suppliers and/or consumers. In these companies, the package becomes a frequently used object to complement product features and achieve an effective and efficient means of logistics.

In this context, it is interesting to integrate package development in the product development process. To corroborate these thoughts, the overall objective for this thesis is to *contribute to efficient and effective resource utilisation in global enterprises by providing an overall procedure model for integrating product and package development.*

Starting with three surveys in Swedish mechanical, pharmaceutical and food industries, which account for approximately 74% of all packaged products produced in Sweden, the potential for the concept was explored and positively validated. By comparisons across survey results and additional information provided by literature reviews of mechanical, pharmaceutical and food product development, the possibility of introducing integrated product and package development into an integrated procedure model has been established. To also include the package developer's perspective, survey results are complemented with five case studies on the package development process in industry. Additionally, a theoretical exploration has been performed in literature on the concept of integration in product development. Here the applicability of some theories have been evaluated through real industry cases.

An integrated product and package procedure model is heavily dependent upon product area. The dependence between product and package design leads to technical, organizational, process and goal oriented implications for the development project. This means that when the product area is known, relevant measures for the integration of product and package activities on an operational level can be developed into the procedure model. Here general recommendations are based on the integration of mechanical engineered products and their adherent packages. For the integration of product and package it is (1) important to include the package in the product mission statement, (2) preferable to consider the function decomposition of product and package when specifying the product and (3) beneficial to also decide upon the package hierarchy and package materials when deciding on detailed product systems and subsystems.

Sammanfattning

Följande text är en populärvetenskaplig sammanfattning av denna avhandling.

De flesta företag arbetar idag på global basis. För ett företag som utvecklar, tillverkar och distribuerar produkter innebär detta att företagsverksamheten oftast är spridd i ett nätverk av kontakter där 1) utveckling och tillverkning sker vid företagets divisioner i flera länder och 2) distribution av material, produktens delsystem, och sker mellan dessa divisioner. Ett globalt företag samarbetar också med leverantörer i flera länder och riktar sig oftast även till konsumenter över hela världen. Detta innebär att distributionen av komponenter och delsystem av produkten även inbegriper 3) nationellt spridda leverantörer samt att 4) färdigproducerade produkter skall skickas till konsumenter över hela världen från olika placering av monteringsfabriker.

Detta komplicerade globala nätverk av samarbetspartners skapar ett ökat behov av transport, hantering och lagring av komponenter, delsystem och slutmonterade produkter inom företaget, dvs. mellan företagets divisioner, samt mellan företaget, dess leverantörer och slutkunder. Varje tillfälle av lagring, transport, hantering mellan parter i nätverket skapar specifika behov för t.ex. att skydda komponenter, informera den som hanterar produkten eller skydda omvärlden från produkten etc. Detta bidrar till höga krav på att anpassa produkten, dess komponenter och delsystem till ett komplicerat behov av krav gällande hantering, transport och lagring. Dessa logistiska krav kan gälla allt från skydd av komponenter till anpassning till transportstandard och/eller lagar och regler.

För att tillgodose behoven väljer man ofta att komplettera produkten med en eller flera förpackningar och skapar därmed ett Produkt-Förpackning-System (PFS). Tillsammans tillgodoser produkt och förpackning de krav och behov som ställs för att möjliggöra transport, hantering och lagring.

Det så kallade PFS är en ofta förbisedd aspekt i produktutveckling. Idag utvecklar man oftast produkten först och kompletterar den sedan med en förpackning. Detta gör att man förbigår möjligheten att skapa ett ultimat PFS och att utnyttja förpackningens kompletterande egenskaper till produkten full ut. Detta skulle t.ex. innebära att man vid val av förpackning inte anpassat produkten till gällande förpackningsstandard/transportstandard eller att produkten konstrueras i

ett dyrare och tåligare material än nödvändigt då man inte beaktat förpackningens billigare men skyddande egenskaper vid utveckling av produkten. Förpackningen, precis som produkten, skall ses i ett större sammanhang.

Denna avhandling är ett första steg i att verifiera betydelsen för integrerad produkt- och förpackningsutveckling. Den har ett syfte att möjliggöra en effektiv och långsiktig utveckling av PFS. Målet är att bidra med en operationell utvecklingsprocess för integrerad produkt- och förpackningsutveckling.

För att nå dit startar denna avhandling i en undersökning av tre produktområden i svensk industri: mekaniska produkter, livsmedel samt farmaceutiska produkter. Dessa produktområden motsvarar ungefär ~74% av alla förpackade produkter i Svensk industri. Denna första empiriska undersökning visar ett stort intresse för integrationskonceptet i produkttillverkande industri.

Tillsammans med litteraturstudier fastställs att en integrerad produkt- och förpackningsutvecklingsprocess är starkt beroende av produktområde. Av samma anledning begränsas integrationskonceptet till att först introduceras inom produktområdet för mekaniska produkter.

För att bidra till alla perspektiv som skulle inbegripa en integrerad produkt och förpackningsutvecklingsprocess fortsätter sedan denna avhandling att utforska även förpackningsindustrin i 5 fallstudier om förpackningsutveckling. Dessa fallstudier kompletterar existerande teori om förpackningsutveckling och bidraget är ett förslag till en förpackningsutvecklingsprocess. För att förpackningsindustrin dra nytta av integrationskonceptet behöver dessa skapa helhetssyn i utveckling av förpackningar och utveckla sin kunskap som leverantör gällande logistik och slutkunders behov.

Slutligen skapas en modell för integration av produkt och förpackningsutveckling.

Slutsatsen av denna avhandling är att integrerad produkt- och förpackningsutveckling är intressant för dagens industri som bör anpassa sina processer och verksamhet därtill. Konceptet kommer att bidra till förändring i affärsverksamhet för produktillverkande och förpackningstillverkande företag, men även nya möjligheter för andra aktörer som konsulter. Fördelar och möjligheter finns för de aktörer som bäst kan bidra till en helhetssyn gällande utveckling av förpackade produkter

List of appended papers

The following papers constitute the core results of this doctoral dissertation.

Appended paper I

Bramklev, C., Bjärnemo, R., Jönson, G. (2001) *Concurrent Design of Product and Package – extending the concept of IPD*, Presented and published in the proceedings of the International Conference on Engineering Design (ICED01), 21-23 August, Glasgow.

Bramklev and Bjärnemo collected all empirical content, performed analysis and jointly wrote the paper. Jönson played an advisory role. This paper is also published in Eng. Lic. thesis 08/2004, Department of Design Sciences, Lund University.

Appended paper II

Bramklev, C., Bjärnemo, R., Jönson, G. (2004) *Increasing competitiveness through concurrent development of product and packaging*. Presented and published in proceedings of the International Symposium on Tools and Methods for Competitive Engineering, TMCE 2004, April 13-17, Lausanne.

Bramklev collected all empirical content, performed analysis and wrote the paper, with Bjärnemo as advisor and Jönson providing comments. This paper is also published in Eng. Lic. thesis 08/2004, Department of Design Sciences, Lund University.

Appended paper III

Bramklev, C., Bjärnemo, R., Jönson, G. and Johnsson, M. (2005) *Towards an integrated design of product and packaging.* Presented and published in the proceedings of the International Conference on Engineering Design (ICED05), 15-18 August, Melbourne, Australia.

Bramklev performed analysis and wrote the paper, with Bjärnemo as advisor and Jönson providing comments. Johnsson provided additional empirical material, which Bramklev analyzed.

Appended paper IV

Bramklev, C. (2007) *On a Proposal for a Generic Package Development Process.* Technical paper, Department of Design Sciences, Faculty of Engineering at Lund University, Sweden. Submitted to *Packaging Technology and Science – An International Journal.*

Bramklev designed the study, collected and analysed empirical content and wrote the paper.

Appended paper V

Bramklev, C., Hansen, C.T. (2007) *On the logistics effects of integrated product and package design.* Published in the proceedings of the International Conference on Engineering Design 2007, ICED'07, 28-31 August, Paris, France.

The paper is a result of joint research between Lund University and Technical University of Denmark (DTU). Bramklev collected all empirical material and Hansen provided theory for analysis. The paper was jointly written by Bramklev and Hansen, Bramklev being the main contributor.

Appended paper VI

Bramklev, C. and Bjärnemo, R. (2007) *Product and Package Development – an Integrated Approach*. Technical paper, Department of Design Sciences, Faculty of Engineering at Lund University, Sweden. Forthcoming journal publication.

Bramklev and Bjärnemo jointly designed the study and collected empirical material. Bramklev conducted the analysis with support of Bjärnemo. The paper was jointly written by both authors, Bramklev being the main contributor.

Other related publications

The following papers constitute additional related results to this doctoral dissertation.

Thesis

Bramklev, C (2004) *Concurrent Development of Product and Packaging – towards an integrated development procedure.* Licentiate of Engineering Dissertation nr 04/1008. Lund Institute of technology at Lund University, Department of Design Sciences, Division of Packaging Logistics.

Technical reports

Bramklev, C (2007) *The package development process.* Technical report, ISBN 978-91-976278-8-7. Lund University, Department of Design Sciences, Division of Packaging Logistics.

Bramklev, C (2008) *Packaging technology.* Technical report, ISBN 978-91-976278-9-4, Lund University, Department of Design Sciences, Division of Packaging Logistics.

Journal publication(s)

Bramklev, C. (2007/2008) *A survey on the concept of integrating product and package development*. Submitted to the International Journal of Production and Technology Management, special issue on Product Lifecycle Management.

(continued on next page)

In conference proceedings

Bramklev, C. (2007) *On the concept of "integration".* Technical paper, Department of Design Sciences, Faculty of Engineering at Lund University, Sweden. Submitted to TMCE Symposium, Turkey, 2008.

Motte, D., Bramklev, C., Bjärnemo, R. (2007) *A method for supporting the integration of packaging development into product development.* Presented at and published in proceedings of 14th CIRP International Conference on Life Cycle Engineering, 11-13 June, Tokyo, Japan.

Beckeman, M., Bramklev C. (2007) *Past, present and future roles of the package in logistics.* Presented at and published in proceedings of 19th NOFOMA Conference, 7-8 June, Reykjavik, Iceland.

Bramklev, C., Bjärnemo, R., Jönson, G. (2004) *Towards integration of product and packaging development.* Published in Licentiate of Engineering Dissertation nr 04/1008, Lund Institute of Technology at Lund University, Department of Design Sciences, Division of Packaging Logistics.

Bramklev, C. (2000) *The requirement of an integration model in Packaging Development*, working paper presented at and published in proceedings of NOFOMA 2000, June, Aarhus.

Table of contents

APPENDED PAPERS

1 Introduction

This chapter serves as an introduction to the concept of integrating product and package development. It contains descriptions of the problem, research background, as well as objectives and scope of the thesis. In addition, the chapter will also introduce the structure of the thesis.

1.1 A problem in global enterprises

Deregulation and expansion of trade in the world economy together with increased competition have created new premises for producers of products and packages. In the search for new market opportunities, enterprises exploit potential new customers and additional revenue by extending markets to also include broader international markets (Dunning, 1988; Vernon, 1966). This is the foundation of the global enterprises. (Dicken, 2003; Porter, 1998)

A global enterprise is formed around a network of enterprise divisions, suppliers and customer markets spread geographically around the world. This creates an inner and outer market of the global enterprise. In comparison to the traditional centralised enterprise, the inner market within the global enterprise creates extensive demands for transportation, handling and storage of raw-materials, parts, sub-assemblies and final products. This is also the case for the outer market, since the customers of the global enterprise are dispersed all over the globe.

An inevitable outcome of this practise is the demands for extensive use of packages for the raw materials, parts, sub-assemblies and final products. This practise causes increased lead time, costs and negative effects on the environment. In this context it is interesting to acknowledge the role of the package. If all products were fully lifecycle adapted there would be no need for any packages, and the problems outlined above would be solved. However, such products are extremely rare, if existing at all. For the same reason, making packages is absolutely necessary, which creates a Product-Package-System (PPS).

In order to maintain and/or increase competitiveness, global enterprises have to reduce lead time and costs. Today it is also beneficial to create an environmentally friendly profile.

In an attempt to obtain these goals, Bjärnemo, Jönson and Johnsson (2000) proposed an integrated approach to the development of product and package. Such an approach would, in a product lifecycle perspective, facilitate allocating essential functions between product and package. One example is to avoid costly reinforcement of a product to withstand the extreme (transient) loads during transportation, handling and storage by introducing a package.

1.2 Research background

To contribute to the successful establishment of global enterprises, an interdisciplinary research project was launched at the Department of Design Sciences, Lund University, as a collaborative effort between two of its divisions - Machine Design and Packaging Logistics. The overall objective established for the project was to: *"facilitate the establishment of successful global enterprises by providing methods, techniques and an overall procedure model for integrating packaging logistics into the product development process."* The project was of a conceptual nature and was presented in Bjärnemo, Jönson and Johnsson (2000).

1.3 Research questions of this thesis

In the autumn of 2000 the research project reported in *this* thesis was launched. The first research question (RQ 1) to be answered in this project is:

> Is there industrial support for the establishment of an integrated product and package development process?

Note that the answer to this question is not a simple "Yes" or "No", but more an indication of the awareness of and interest in the underlying problem area in industry.

The second research question (RQ 2) to be answered in this project is:

> How can an integrated development process for product and package development be accomplished?

1.4 Research objectives

The overall objective set out for this thesis is to:

> Contribute to efficient and effective resource utilisation in global enterprises by providing an overall procedure model for integrating product and package development.

Based on the overall objective, the following sub-objectives have been formulated:

1. Establish the current status regarding the proposed integration concept (for product and package development) in theory.
2. Establish the support for the proposed integration concept in the product manufacturing industry.
3. Propose an updated package development process well adapted for integration into the product development process.
4. Provide a first version of a generic and operational integrated product and package development process.

Since current product development processes are well established in industrial practise, there is no need for studying their current status in practise.

The objective here is based on an unbiased approach to the development of such an integrated product and package development process model. Here the product life cycle[1] is to be used in addressing interactions between product and package. Additionally, dependence in product and package development processes is to be used in addressing interactions between the product development process and the package development process. Hence improvements in resource utilisation in the product development process and subsequent phases of the product life cycle are expected.

---

[1] Here the product life cycle, as opposed to the market life cycle (see Kotler & Armstrong, 1994), is referred to. This means that the product is considered as an object from the establishment of the need of the product until it is fully consumed or used.

1.5 Demarcations

For practical reasons it is necessary to constrain the surveys of the product manufacturing industry. The following product areas, representing 74% of the manufacturing industry in Sweden (Thorén & Vinberg, 2000), have been selected: *mechanical products, food products* and *pharmaceutical products.*

The classification of a product as *mechanical* is simply based on the fact that its main working principle constitutes the technical realisation of an effect emanating from mechanics, or that a majority of its sub-systems are, in turn, based on mechanical working principles. The classification of a product as *food* is based on the fact that the product is used as food or beverage for humans, or used as a component of any such article. The classification of a product as *pharmaceutical* is defined according to FDA regulations[2] regarding drugs and medical devices.

Finally, it is also necessary to constrain the product area for the integrated product and package development process. It is here constrained to the mechanical product due to the expertise available to the researcher within product development in this research area.

1.6 Overview of this thesis

This chapter has set the problem statement of this thesis and positioned the problem under investigation.

The second chapter is about the research process and discusses the research design and methods used for the empirical study.

The third chapter is the frame of reference and provides discussion on product development, package development and the phenomena of integration in product development.

The fourth chapter is a synthesis of thesis studies, results and appended papers.

Finally, *the fifth chapter* states conclusions, reflections, contributions of thesis, and provides implications for further research.

---

[2] FDA regulations refers to "FEDERAL FOOD, DRUG, AND COSMETIC ACT" as amended by the FDA Modernization Act of 1997

2 The research process

The following chapter describes the path followed during the research process resulting in this thesis. It starts with a discussion of the overall research approach, and continues with the decisions made in the research process, with notes on implications for the overall research approach.

2.1 The overall research approach

The research background for this thesis was, as previously mentioned, the project reported in Bjärnemo, Jönson and Johnsson (2000).

The actual point of departure of *this* thesis research project was an exploratory literature review set out to fulfil the first sub-objective stated: *establish the current status regarding the proposed integration concept (for product and package development) in theory*. No related works fulfilling the thesis' overall objective were found.

Guided by the first research question and due to the lack of identified related work on the thesis topic, the second sub-objective was stated to *establish the support for the proposed integration concept in the product manufacturing industry*. This implies that information from a number of companies must be obtained to explore and describe the awareness of and interest in the problem area. Thus, a *survey method*, based on a qualitative approach, was chosen to collect the information needed.

To cover and explore the widest range of packaged products possible within this thesis research project, the following three product areas were chosen: *mechanical products, foods* and *pharmaceuticals.* Together the three product areas cover approximately 74% of all packaged products produced in Sweden (Thorén & Vinberg, 2000).

To provide an overall integrated procedure model for the development of product and package it is necessary to investigate the imperatives not only of product development, but also of package development. An initial review of package development has indicated significant differences between theoretical descriptions of package development processes. To gain a deeper insight into development of packaged products on an operational level, a *pilot case study* was launched to investigate current practise of package development in industry. Indications from this study show a discrepancy between theory and practise, which in turn calls for deeper understanding of current package development practise in industry. To obtain this understanding *a multiple case study* was performed in the package manufacturing industry. The results of this multiple case study confirmed the indications from the pilot case study, but more importantly, also highlighted the shortcomings of existing package development processes to facilitate *integration* into the product development process. To accommodate the second research question it is therefore necessary to update current package development theory, which in the research project was introduced as the *new* third sub-objective. It is stated as follows: *propose an updated package development process well adapted for integration into the product development process*. To fulfil this sub-objective the *previously performed multiple case study* was supplemented with an *extensive literature review* on package development theory.

The fourth step is to accommodate an integration model as stated in the fourth sub-objective: *provide a first version of a generic and operational integrated product and package development process.* In a first attempt to develop an integrated product and package development process, model information from *previous empirical survey studies* and *the package pilot case study* was used. During this first attempt to develop an integrated process model, the magnitude of the integration problem became more obvious. This observation resulted in the need for an extensive review of the concept of integration between development processes. To check the applicability of some theoretical results, *a multiple case study* applied to product examples and development cases was performed in industry.

Finally, by using the findings of the review of the concept of integration, previously published empirical results and the previously developed package development process, an integrated product and package development process was established.

The overall research approach, founded on research questions and objectives, has been performed in a number of studies and is described in Figure 2.1 (also providing notes on contributions to appended papers).

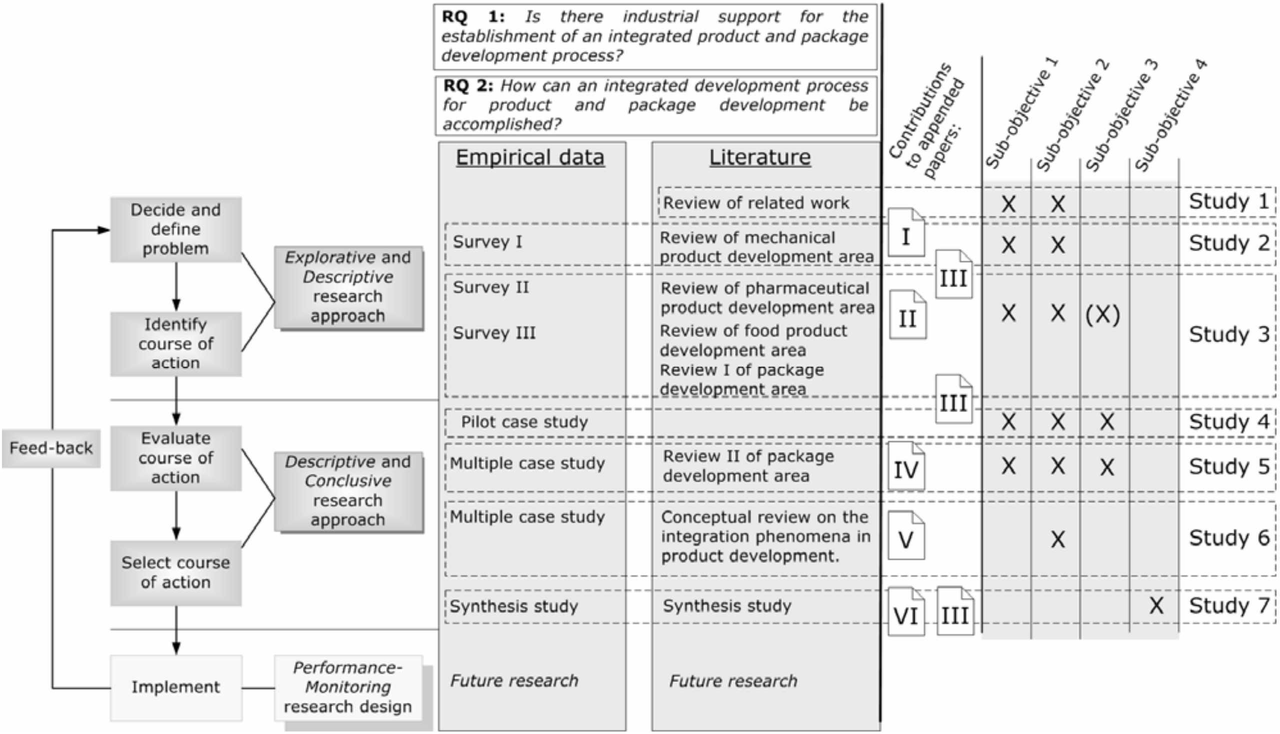

Figure 2.1 The overall research approach

2.2 Notes on decision of research methods

The overall research approach here is based on the scientific perception that theories are models of reality and may be improved to provide a better description of reality. To improve the theoretical models one uses scientific methods, such as literature studies, logical structuring, empirical observations, simulation etc.

The research approach discussed here consists of seven studies organised into a dynamic and sometimes iterative journey. Both empirical and theoretical insights have been gained, sometimes resulting in changes of the original research approach. Each decision on research method for this thesis is extensively discussed in each of the appended papers. However, external publication of research papers usually constrains the author to fully elaborate on underlying theories and research method. The following section provides complementary notes on research methods. It is also intended to provide deeper understanding of the studies performed, by, implicitly, providing an account of the underlying theories upon which these studies were built.

2.2.1 Study 1

Decision on research method of study 1 is reported in *Bramklev (2000)* and *Bramklev (2004)*.

Study 1 includes a *literature review* on related work.

2.2.2 Study 2

Decision on research method of study 2 are reported in *Paper I (Bramklev, Bjärnemo & Jönson, 2001)* and *Bramklev (2004)*.

Study 2 includes an *extensive literature review* (Hart, 1998) and combines an *explorative survey method* (Kinnear & Taylor, 1996; Malhotra, 1996) with a *descriptive survey method* (Leedy, 1997). The information retrieval is *structured* (Firestone, 1987; McClintock, Brannon & Maynard-Moody, 1979), including *personal interviews* and a *questionnaire technique*. The questionnaire is organised into six topics on product and package development, and uses both *dichotomous* and *open-ended questions* asking for mainly *qualitative data* (Firestone, 1987; Jick, 1979; McClintock, Brannon & Maynard-Moody, 1979). The *non-probability sample* consists of 20 companies developing, manufacturing and distributing packaged mechanical products.

2.2.3 Study 3

Decision on research method of study 3 is reported in *Paper II (Bramklev, Bjärnemo & Jönson, 2004b)* and *Bramklev (2004)*.

Study 3 combines a minor *literature review* (Hart, 1998) on the package development process with the same the research method used in study 2. The only difference to the research method used for study 2 is that this study includes two different product areas: the pharmaceutical product area and the food product area.

2.2.4 Study 4

Decision on research method of study 4 is reported in *Paper III (Bramklev et al., 2005)* and *the technical report on package development (Bramklev, 2007c)*.

The study combines the minor *literature review* (Hart, 1998) on the package development process performed in study 3 and a single case study (*the pilot case study*) (Eisenhardt, 1989; Yin, 2003) on current practice for package development in industry. The choice of case company is built upon the *theoretical sample* (Eisenhardt, 1989) of package material suppliers identified in studies 1 and 2. Access to the case company is provided because a package supplier known to the researcher is willing to "help out".

The project is planned as an *action research* project (Argyris & Schön, 1991; Ballantyne, 2004) and uses *multiple data collection methods* (Jick, 1979; Miles & Huberman, 1994) when combining *in-depth interviews* (Leedy, 1997; Malhotra, 1996) (including six topics) and the study of *archival sources* (Kinnear & Taylor, 1996; Malhotra, 1996). Inspired by Glaser and Strauss (1967) *coding, retrieval and analysis of data are joined* and while collected go through daily *speed analysis.*

2.2.5 Study 5

Decision on research method of study 5 is reported in *Paper IV (Bramklev, 2007e)* and *the technical report on package development (Bramklev, 2007c)*.

The study combines an *extensive literature review* (Hart, 1998) on package development processes with *a multiple case study* (Eisenhardt, 1989). The multiple case study is to identify the dependence of process activities *within* the package development process and *to* the product development process from a package development perspective. A case study method benefits in providing additional operational information on package development, which current package development theory does not cover. Thus, the multiple case study tactic is here valuable in building theory (Eisenhardt, 1989). *Theoretical sampling* (Eisenhardt, 1989) and *replication logic* (Yin, 2003) is used to build the multiple case study, finishing with five cases. The case study focuses on a wide variety of, mainly, *qualitative data*.

Data collection is performed in a combination of *semi-structured interviews* (Leedy, 1997; Malhotra, 1996) (including six topics), *archival sources* (Kinnear & Taylor, 1996; Malhotra, 1996) and a *process modelling* method (Browning, Fricke & Negele, 2006; Ljungberg & Larsson, 2001; Melan, 1993). The process modelling method is added to improve the case study approach and complement the original combination of observational, archival and interview methods used in the pilot case. The process modelling method turns out to be a valuable addition to describe the package development process and the interaction/dependence between product development and package development.

2.2.6 Study 6

Decision on research method of study 6 is reported in *Paper V (Bramklev & Hansen, 2007)*.

The study uses *an explorative literature review* (Hart, 1998) to update findings on related work on the concept of integration, but also integrated product and package design.

The empirical evaluation of the integration concept is founded upon dispositional effects (Olesen, 1992) and evaluation of the logistics effects of the Product-Package-System (PPS) through a gallery technique (Olesen et al., 1996). To check applicability, theories are here applied to product examples and design cases.

For the evaluation, a *multiple case study* (consisting of 3 cases) is used. The case method is based on *theoretical sampling* and *replication logic* (Yin, 2003). For data collection, *semi-structured interviews* and *archival sources* are used.

2.2.7 Study 7

Study 7 is a synthesis of results and decision on research method as reported in *Paper VI (Bramklev & Bjärnemo, 2007)*.

The practical problem(s) of integrating product and package development is founded in observed phenomena that are diagnosed and analysed in industry and related research (literature). In parallel, the problem of the integration phenomena is analysed in its theoretical context, thus providing important contributions to the establishment of *integration* in the product and package development process. Figure 2.2 below illustrates this process.

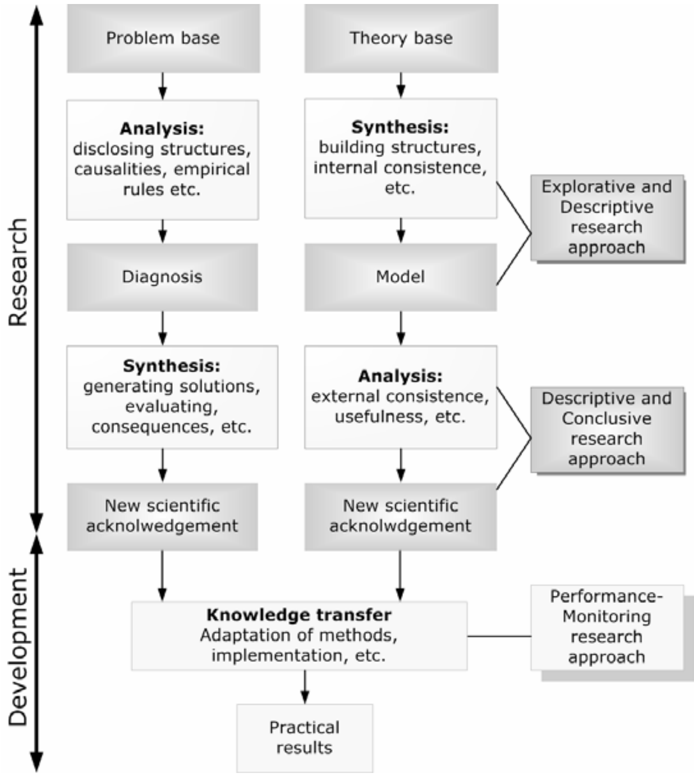

Figure 2.2. The interplay between theory and practice in applied research. (Author's elaboration on Jörgensen 1992 (in Olesen, 1992)).

Table 2.1 below summarises the methods used and their relation to the individual appended papers.

Table 2.1 Decision on research method reported in the appended papers

Papers	*Survey*	*Case study*	*Literature review*
Paper I	Explorative / Descriptive Questionnaire: 6 topics Personal interview Non-probability sampling Sampling unit: 20		Mechanical engineering design and development
Paper II	Explorative/Descriptive Questionnaire: 6 topics Personal interview Non-probability sampling Sampling unit: 20x2		Development processes: -Food product -Pharmaceuticals -Packages
Paper III	Explorative/Descriptive Questionnaire: 6 topics Personal interview Non-probability sampling Sampling unit: 20x3	Pilot case study (1) Theoretical sample Semi-structured, in-depth interviews Archival sources	Development processes: -Mechanical products -Food products -Pharmaceuticals -Packages
Paper IV		Multiple case study (5) Theoretical sample Replication logic Semi-structured, in-depth interviews Archival sources Process modelling observational techniques	Package development Packaging Development
Paper V		Multiple case study (3) Theoretical sample Semi-structured, in-depth interviews Archival sources	Integrated Product and Package Design
Paper VI	Synthesis of previously published survey results	Synthesis of previously published case study results	Integrated product development Product development: -mechanical product -packages

3 Theoretical frame of reference

The following chapter describes the theoretical foundation applied in this thesis. It constitutes the theoretical framework of product development and package development, and discusses theory on integration of development processes.

3.1 On Product Development

In order to give an overall perspective on product development, it is initially presented here in its embedded context — the *product innovation process*. This process starts with the identification of a market need and ends with the successful launch of the product on the market. The following subprocesses constitute the product innovation process: product planning, product development manufacture and assembly, distribution and sales. Figure 3.1 below illustrates the product innovation process.

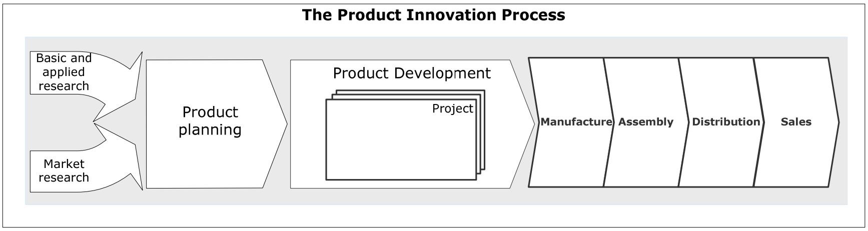

Figure 3.1 The product innovation process

The *product planning process* takes place before the actual product development project is approved. During this process the search for opportunities, especially emanating from market, and research and development (R&D), is conducted; the opportunities are identified and prioritised into a set of product project proposals or a product portfolio. In the product plan, the portfolios of product/portfolios to be pursued are presented. For each and every one of these product proposals in this plan a *(project) mission statement* is established, which constitutes the input information to the actual product development project (Ulrich & Eppinger, 2007).

Ulrich & Eppinger (2007) describe product development as *"a set of activities beginning with the perception of a market opportunity and ending in the production, sales and delivery of a product."* Is should be noted that as long as the technical performance of a product constituted the single most important competitiveness factor on the market, engineering design alone represented the most important function to achieve this competitiveness. However, as the focus shifted to customer needs the necessity of a multi-disciplinary approach to the overall development, *product development*, became inevitable. In other words, engineering design becomes embedded into product development.

Succeeding product development are manufacturing and assembly of the product-to-be. These constitute the core activities within production (function). The final activities before a successful launch of a product-to-be are distribution and sales.

In this thesis two central themes of product development are important: *the product-to-be* and *the process* of development. These are elaborated upon in some detail below.

3.1.1 The product

A product may be a service or a physical object and, according to Roozenburg and Eekels (1995), is used as *"an instrument in human action"* to fulfil a set of values and needs of a person or an organisation. Kotler (1994) states that the product may be either *tangible* or *intangible* (also termed *service*). However, the focus in this report is on man-made physical products, also designated as *artefacts*.

Artefacts have many classifications. A considerable amount of literature focuses on describing engineered, discrete and physical artefacts. According to Ulrich & Eppinger (2007), such artefacts are *"…products conceived, produced, transacted and used by people because of the properties and functions they may perform."* In other words, customer values and demands correspond to a number of functions that are realised as properties in the materialised product, see Figure 3.2 below (Roozenburg & Eekels, 1995). What engineered artefacts have in common is that they can be described by their product design through the combination of *function structure*, *main working principle* and *the embodiment* (Pahl & Beitz, 1996; Roozenburg & Eekels, 1995).

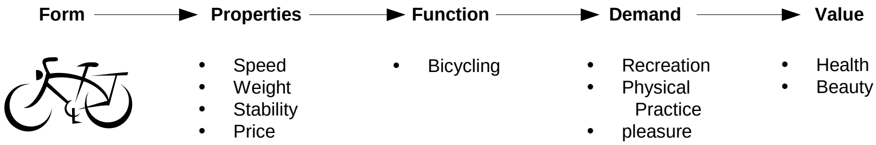

Figure 3.2 The relation between form, properties, function, and customer demand and values. (Authors elaboration on Roozenburg & Eekels, 1995)

The classification of a product through its *function structure* is a representation of the intended behaviour of the product. In other words, customer demands are transformed into functions, which are abstract formulations of the task the product shall perform to fulfil customer demands. The set of functions a product shall fulfil may vary. To make a meaningful and compatible description of the product, functions are structured into a combination of sub-functions and overall function, thus the term *function structure*. (Pahl & Beitz, 1996; Roozenburg & Eekels, 1995)

A product may also be classified by its *main working principle* (Pahl & Beitz, 1996). For example, classifying a product as mechanical is simply based on the fact that its main working principle constitutes the technical realisation of mechanical effect(s), or that a majority of its subsystems in turn are based on mechanical working principles.

The product may also be classified on the basis of its *embodiment* including its architecture or layout. Examples of these are platform products, and modularised products, and integral product architectures (Ulrich & Eppinger, 2007). The embodiment of the product also includes shapes, forms, dimensions and surface properties of all the individual components, thus also including materials (Pahl & Beitz, 1996; Roozenburg & Eekels, 1995).

In an additional approach, provided by Kotler and Armstrong (1994), a product may be divided into product-classification schemes based on product characteristics and consumer preferences. Two common product classification are *consumer goods*, which are products bought by final consumers for personal consumption, and *industrial goods*, which are products bought by individuals or organisations for further processing or use in conducting a business.(Kotler & Armstrong, 1994)

3.1.2 The development process

A second central theme in product development, discussed here, is *the process* followed when developing a product. A process is a well-defined set of interrelated activities connected through the transformation of inputs into outputs (Ljungberg & Larsson, 2001; Melan, 1993).

Management literature characterises a process by: (1) a clearly defined ownership, (2) defined boundaries, (3) documented flow of work, (4) established control points, (5) established measurements and (6) control of process deviations, (7) and usually repeated many times in the same manner creating value to an intended customer(s) (Hammer, 2001; Melan, 1993; Pall, 1999). One can say that all companies have processes, but not all are modelled, documented, consistent, effective or efficient (Browning, Fricke & Negele, 2006). The intent of a *process description* is to facilitate an overall strategy describing *what* activities constitute the process and *in what order* these activities are to be carried out (Ljungberg & Larsson, 2001; Melan, 1993).

Only a small portion of the extensive body of knowledge on process management and process modelling focuses on the product development processes. According to Browning, Fricke and Negele (2006), most of this literature is aiming at business and manufacturing processes. However, since product development processes are different in character, it is important to acknowledge their characteristics, as pointed out by e.g. Browning & Ramamesh (2007), Finger & Dixon (1998), Hovárth (2004), Krishnan & Eppinger (2001), Smith & Morrow (1999), Unger & Eppinger (2002).

According to Browning, Fricke and Negele (2006), product development processes are characterised as being creative and innovative, dynamic, interdisciplinary, strongly interrelated, strongly parallel, interactive, communication intensive, anticipatory, planning intensive, uncertain and risky. Furthermore, a product development process should not solely focus on the product or the process, but on a combined approach (Huang & Gu, 2006; Negele, Fricke & Igensberg, 1997).

Product development processes differ due to the product characteristics that affect the set of activities and their relationship (Ulrich & Eppinger, 2007). For example, Bramklev (2004) identifies these types of discrepancies between the process activities in development processes of pharmaceutical, food and engineering products.

The goal of the development process is to provide new and unique solutions even though the process follows a repeatable pattern/structure. For example, Krishnan and Ulrich (2001) state that engineering product development processes include a set of general decisions.

For the *description* of a product development process it is important to clearly distinguish between *reality* (the way work really gets done) and *the model* (the abstract description of the way work can or should be done). The term *process* is used in both cases.

According to Ulrich and Eppinger (2003, p.13) a product development process can be *described* in three perspectives:

- as "the initial creation of a wide set of alternative product concepts and the subsequent narrowing of alternatives and increasing specification of the product until the product can be reliably and repeatably produced by the production system"
- "as an information-processing system…in which various activities process the development information"
- "as a risk management system…as the process progresses, risks are reduced as the key uncertainties are eliminated and the functions of the product are validated".

Another perspective on the description of a product development process is, as given by Browning and Ramasesh (2007), that product development process models can have four main purposes. They state that the description of a product development process in a model is founded on four main category purposes: *project visualisation, product development planning, product development execution* and *control, product development project development*.

Additionally, Browning, Fricke and Negele (2006) discuss how a process model can be either *prescriptive* or *descriptive*. A *descriptive* process model attempts to capture tacit knowledge about how work is really done, is built inductively and tries to describe an "as is" reality. A *prescriptive* model tells people what work to do and perhaps also how to do it. It is built deductively and is usually a standard process accompanied by mandates to follow more exactly. However, many process models share some descriptive and prescriptive characteristics. Key to a good process model is that it pays special attention to influences among activities (Browning, Fricke & Negele, 2006).

Keeping these characteristics in mind, on an operational level companies choose from a variety of processes (representations of reality) and methods to iterate through development so as to mitigate risk and manage product development effectively (Unger & Eppinger, 2002). Unger & Eppinger (2002) demonstrate strong varieties between product development processes such as *stage-gate/waterfall processes, spiral processes, the design to schedule/budget process,* and *the evolutionary delivery process*. As a reference, some of the most widely cited design models for reasoning from function to form are organised into stages/phases; see e.g. French (1985), Pahl & Beitz (1984), and Hubka (1989). The same applies for well-known product development processes; see e.g. Ulrich and Eppinger (2007), Andreasen (1987) and Olsson (1985).

A central idea in product development is the ability to *generalise* the product development process, i.e. describe the *generic* product development process. As mentioned above, product characteristics affect the set of activities and structure of the development process.

Following is a short summary of the literature of product development structured according to three product classifications: *mechanical products, pharmaceutical products* and *food products*.

The mechanical product development process

Some of the most widely cited and utilised procedure models within the product manufacturing industry originate from the area of mechanical engineering; see e.g. Andreasen and Hein (1987), Olsson (1985), Roozenburg and Eekels (1995), Ullman (1992), Ulrich and Eppinger (2007). According to Ulrich and Eppinger (2007), the generic product development process for engineered, discrete and physical products consists of five phases: *concept development, system-level design, detail design, testing and refinement* and *production ramp-up*. An illustration of this product development process is provided in Figure 3.3.

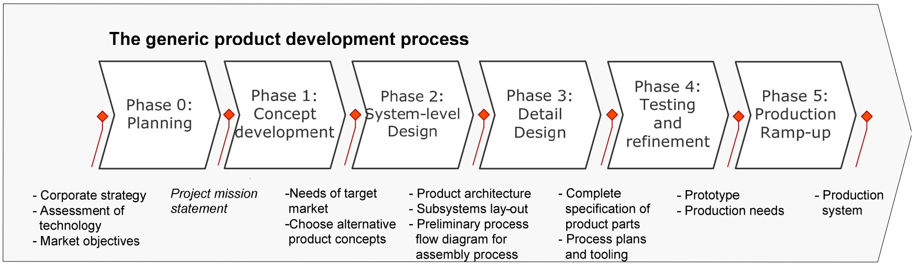

Figure 3.3 The generic product development process based on Ulrich & Eppinger (2007).

In the *concept development* phase, the needs of the target market are identified and alternative product concepts are generated. Finally, one or more concepts are selected for further development and testing. *System-level design* includes the definition of the product architecture and the decomposition of the product into subsystems and components. This phase ends with a geometric layout of the product, a functional specification for each product subsystem and a preliminary description of the final assembly process. *Detail design* includes the complete specification of the geometry, materials and tolerance of all the unique parts in the product and the identification of standardised parts to be purchased. The output of this phase is the control document for the product. *Testing and refinement* involves the construction and evaluation of multiple pre-produced versions of the product in order to test whether the product works as designed and satisfies customer needs. Finally, during *production ramp-up* the product is made with the intended production system, the purpose being to train workforce and eliminate any remaining problems in the production phase.

The pharmaceutical product development process

With reference to Spilker (1994), pharmaceutical product development is denominated *medicine discovery* and *medicine development*.

In addition, Thomke, Hippel and Franke (1998) note that the complete pharmaceutical development and approval process, denoted *medicine development* by Spilker (1994), includes three phases. Phase I begins with pre-clinical research devoted to the discovery and optimisation of one or a few “lead” chemical compounds that appear to hold sufficient promise for clinical testing. Phase II, clinical development, includes three clinical phases in which the safety and efficacy of the proposed pharmaceutical are determined and documented. Phase III deals with regulatory New Drug Approval (NDA) review processes. A case study by Prasad and Mashusudan (2004) demonstrates the overlapping of phases in development of pharmaceutical products.

The pharmaceutical product development process is also described as by Lombardino & Lowe III (2004a), see Figure 3.4, which is very similar to illustrations of the pharmaceutical product development process found frequently in pharmaceutical companies.

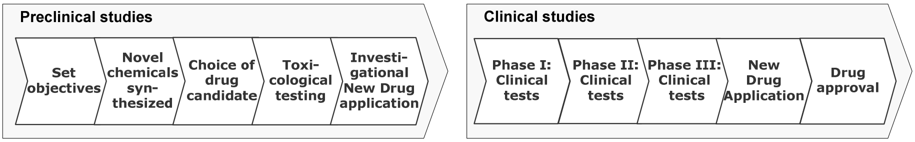

Figure 3.4. The generic pharmaceutical development process based on Lombardino & Lowe III (2004b).

The food product development process

Some examples of the limited amount of publication and research found for food product development are Earle et al. (2001), Graf & Saguy (1991), Fuller (2005), and Moskowitz et al. (2005).

According to Earle (1997), research developed around the product concept, product optimisation and use of computers has led to a more systematic approach, similar to processes used in other product areas.

Food product development includes activities for describing functional characteristics and ingredient formulation, sensory analysis of form, flavour and colours, and formulations for processing variables, shelf-life requirements and ingredient constraints, sketches for package and product interaction, and standardised recipe formulation (Earle, 1997; Meyer, 1984; Rudolph & Marvin, 1995). According to Earle (1997), a generic food product development process consists of the seven phases illustrated in Figure 3.5.

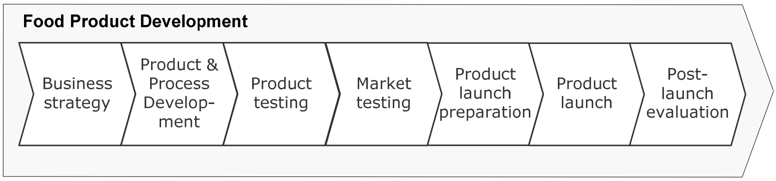

Figure 3.5 Overview of food product development process based on Earle (1997).

3.2 On package development

In a strict sense, the package is also a product and therefore package development process has similarities to the previously discussed product development process. The package artefact and the package development process are discussed below.

3.2.1 The package

The package is here considered an artefact "used in human action" due to the values and needs of a person or a product manufacturing organisation. For the same reason, the package is here described with the product classification terminology discussed above (see Chapter 3.1.1).

One of the first to acknowledge the existence of package functions, hence also implying the existence of a *function structure*, is Paine, F.A. (1990). He states that the main functions performed by a package are protecting, collecting and providing information about the content. This implies that the main functions primarily focus on the demands emanating from the product, i.e. the interaction of product and package, and secondarily focus on customer requirements in the product environment.

Today, with influences from logistics, the initial function structure has evolved to four main package functions: (1) Protect, (2) Contain, (3) Handling utility and (4) Inform (see e.g. Bowersox (2002); Hanlon et al. (1998); Lambert, Stock & Ellram (1998); Soroka (1997); ten Klooster (2002)). Thus, in addition to fulfilling a set of consumer values and demands, the initial purpose of the package is to protect and contain as well as provide handling utility for, and information about, the actual product or contents.

Additional package function descriptions are found in the EU Directive on Packaging and Packaging Waste (1994), interpreted as nine items of package (sub)functions by Packforsk (2001).

In an overall perspective the functions of the package could be condensed as providing the necessary supportive functions to a product to become fully life-cycle adapted (see Figure 3.6 below).

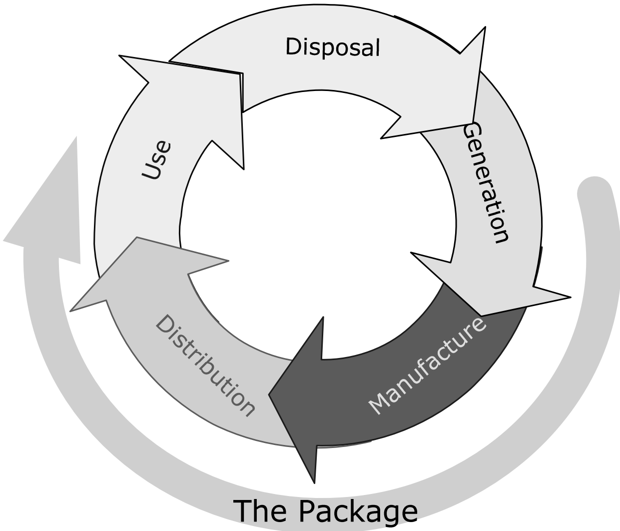

Figure 3.6 The package complementing the product function during the product life cycle.

As discussed in the literature, the dominating main working principle for packages is mechanical, i.e. the main working principle constitutes the technical realisation of mechanical effect(s).

However, note that the solution principles constituting the features of the package are conceived to produce one or many effect(s) in the product environment. In addition to mechanical working principles, other types of working principles are also used in packages. Examples of these are those not directly visible to the eye. For instance, Nielsen (1997) and Rooney (1995) and Finkenzeller (2003) provide examples of active packages and smart packages.

The embodiment of a package, as it is usually conceived, ranges from a simple wrapping to a special-purpose container. In literature, the embodiment of the package is standardised and structured into a three-level hierarchy consisting of primary, secondary, and tertiary packaging (Jönson, 2000; Paine, 1990) - (see Figure 3.7 below). Furthermore, the embodiment of the package is traditionally made of one or a combination of materials such as wood, paper, plastic, glass etc. Note that each material used for a package possesses unique properties, and that a combination of different (package) materials can be used to provide features supporting the product (Hanlon, Kelsey & Forcinio, 1998; Thorén & Vinberg, 2000).

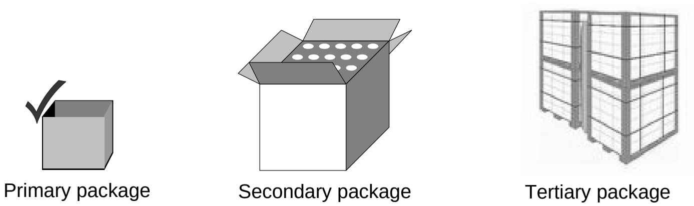

Figure 3.7 The package hierarchy / system

In marketing literature the package is regarded as an important resource. Literature indicates that the product and the package are two integrated items due to marketing reasons (see e.g. Calver (2004), Judd et al. (1989), Melis (1991) and Sonsino (1990)). According to Kotler and Armstrong (1994), packaging includes *"the activities of designing and producing the container or wrapping for a product"*. It is so important that it could be regarded as a 5th "P" in the marketing mix (along with Product, Place, Price and Promotion).

For marketing reasons, i.e. by the package's intended destination and type of customer, the package is also classified in four package types: (1) *Industrial packages*, which are mainly focused on optimising logistical aspects, (2) *Institutional packages*, which are mainly focused on improving institutional logistics aspects, but also enhancing consumer utility, (3) *Consumer packages*, which mainly focus on optimising consumer utility, (4) *Military packages*, which are highly specialised types of protective packages, in which product identification and inspection procedures are emphasised (Hanlon, Kelsey & Forcinio, 1998). Out of these four package types industrial, institutional and military packages may be considered to be (and contain) *industrial goods* and consumer packages are (or contain) *consumer goods*. Also note when Kotler and Armstrong (1994) elaborates on the product definition in his "three levels of product", he regards packaging as part of the actual product (as opposed to the core product and augmented product).

3.2.2 The package development process

Package development is performed either by personnel in the product developing company or by a package developing company (Griffin, Sacharow & Brody, 1985). In other words, the development of packages is normally performed in two separate development processes.

The literature stresses that the product and the package are two integrated items that would benefit from joint development, see e.g. DeMaria (2000); Esse (1989), Harckham (1989), Kooijman (1995), and ten Klooster (2002). In an extensive literature review on the package development process, Bramklev (2007c) discusses the diversity in literature on the package development process descriptions. Authors like Kotler (1980), Lye et al. (2003; 1994; 2000), and Johansson and Weström (2000) provide brief descriptions of the "external" package design procedure model. This is also verified by ten Klooster (2002), who states that there is no documented procedure model that provides a complete guide to the generic packaging design phases.

Some brief examples and discussion on the package development process are provided by Sterling (1982), McGuire (in Giles, 2000), and Melis (1991). More relevant contributions describing a package development procedure model on an operational level are provided by Briston & Neill (1972); Griffin et al. (1985); Paine (1990); W.G. Soroka (1997); DeMaria (2000) and ten Klooster (2002). Figure 3.8 below illustrates DeMaria's "the packaging development process."

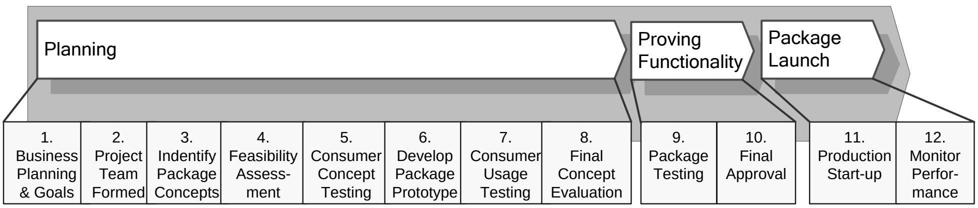

Figure 3.8 The packaging development process according to DeMaria (2000).

3.3 On integration in product development processes

To fulfil the overall objective outlined for this thesis it is important to establish the nature of integration in product development, thus, enabling the development of an integrated product and package development process.

3.3.1 Integration in product development literature

The interpretations of "integration" are many and vary between companies and between researchers. Generally different sources use different terminology for describing the same phenomenon of integration or use the same term for different purposes. The lack of common terminology creates confusion. For example, Gerwin and Barrowman (2002) address the problem with the overwhelming share of studies investigating the relationships between project performance and IPD characteristics, but stress the lack of research "identifying variables and discovering relationships": such research would contribute to the overall description of *integration* within product development.

Literature provides references discussing IPD through several "dimensions". For example, Boyle et al. (2006) updates early research, such as provided by Trygg (1997) and Griffin (1997), by examining the determinants of today's integrated product development practice and develops a model of the *organizational contextual factors* of IPD projects. An organizational dimension is also discussed by Hein et al. (1984) stating that IPD optimize the product's business potential through the simultaneous development of a product's *design, marketing and manufacturing parameters*. Additional dimensions are provided by e.g. LaSala (1990) who discuss how IPD is a systems engineering approach where the constitutive system concepts are *hardware, software, human, design, manufacturing, support and test/testability*. Eversheim et al. (1997) discuss how product development elements, such as *technical systems, procedures, information, methods,* and *activities*, are part of establishing integration. Vajna & Burchardt (2000) provide a Magdeburg model for IPD consisting of procedures and methods, planning and organization, techniques, human and environment.

As such, the phenomenon of integration is discussed basically with two different meanings in literature (Bramklev, 2007b). In the first interpretation integration is used to describe the combining or merging of aspects within a product development project. In a second interpretation, there is a considerable group of sources referring to the essence of integration as the "ultimate" joining of knowledge, making it comprehensive to everyone involved in a product development project. The later case is closely related to various kind of organizational knowledge which is discussed by a large group of researchers (see e.g. Argyris, 1992; Boisot, 1998; Eden & Spender, 1998; Kolb, 1984; Nonaka & Nishigushi, 1999; Ruggles, 1997; Sparrow, 1998; Wiig, 1995).

For integration that matters to product development projects, a more pragmatic approach is provided by e.g. Griffin and Hauser (1996) when they discuss the integration mechanisms (Im) of integrating marketing and R&D in order to bridge dependencies and relationships within product development. Adamsson (2007) exemplifies ten classifications for integration mechanisms in related product development research:

1. Relocation of people
2. Personnel movement
3. Social systems
4. Organisational structure
5. Rewarding system
6. Work procedure and methods
7. Information and communication technologies
8. Computer-aided engineering, product data management, software configuration management
9. Product architecture
10. Training

It is also important to note that the term integration is closely associated with Concurrent Engineering (CE) (see e.g. Clausing, 1993; Sohlenius, 1992; Winner et al., 1988), Simultaneous Engineering (SE) (see e.g. Allen, 1989; Evans, 1988; Eversheim et al., 1997; Goldstein, 1989) and Integrated Product Development (IPD) (see e.g. Andreasen & Hein, 1987; 1991; Olsson, Carlqvist & Granbom, 1985; Vajna & Burchardt, 2000).

Comparing literature (see e.g. Allen, 1989; Andreasen & Hein, 1987; Clausing, 1993; Evans, 1988; Eversheim et al., 1997; Prasad, 1996; Sohlenius, 1992; Winner et al., 1988), the core of the three approaches is as follows:

- The systematic approach to the concurrent design of products and their related processes, such as production development and marketing development.
- The inclusion of all elements of the product life cycle from idea to disposal.
- The concurrent/simultaneous occurrence of activities and events.
- The use of interdisciplinary teams.
- The establishment of a goal to guide and direct the product development procedure model.

According to Matin and Evans (1992), tools are used to support the implementation of concurrent engineering. They classify these tools into three categories: *management based, methods for geometric manipulations of drawings and model* and *formal models.*

Note that the use of formal models is also referred to as *Design for X*, or DFX. According to Huang (1996), the "x" includes performance measurement of product life cycle aspects, and "design" stands for design to ease the "x". For example, "Design for Assembly" (DFA) means the design of the product for ease of assembly, which can be measured through costs. In other words, one is interested in including knowledge on the product lifecycle into the product design and/or development process.

3.3.2 The essence of integration

In pre-historic time a product, or artefact, was designed, manufactured, and used by a single individual. All the knowledge necessary for these activities was amalgamated in this individual, or in other words fully *integrated*. When the artefacts became more complex and the resources were at hand, craftsmen took over design and as well as manufacturing of the products.

During the industrial revolution, design became an independent profession as a result of the need for even more specialised knowledge in the design of products - initially within the field of mechanical engineering. This progression of knowledge specialisation has continued and reached a limit round the 1970s, when broader and more profound knowledge was required to meet the increased demands from the market. To meet the multidisciplinary competence needed for such an effort, *product development* became the answer.

The core idea in product development is to utilise a collective body of knowledge needed during the development of a product in order to meet the requirements from the market. Product development, in other words, represents the reverse process of concentrating knowledge, thus changing the predominant approach for increased specialisation up to the 1970s. Note that this does not imply that the generation of deeper understanding within different disciplines has ceased.

To summarise, in the given context the essence of integration is the efficient and effective use of the collective body of knowledge — in the development of new or improved products.

3.3.3 Enabling integration in product development

In order to efficiently and effectively utilise the collective, or multidisciplinary, body of knowledge in the product development (as discussed on section 3.1.2) it is essential that the process utilised in the execution of a development project accommodates this goal. This is obtained by utilising a model of the development process as previously described – see chapter 3.1.2.

Due to the complexity of the overall development process it is decomposed into less complex and distinguishable sub-problems, also denoted phases. The sequential order of these phases represents a step-by-step "materialisation" process originating from the engineering design process. Each and every one of the phases is in turn decomposed into a sequence of activities. These activities in turn represent sub-problems. During the last decades there has been a converging trend towards a consensus in the product manufacturing industries regarding the decomposition of the phases and the activities constituting the process both in theory and in practise – e.g. as given in Andreasen and Hein (1987), Olsson (1985), Pahl & Beitz (2007), Ullman (1992), Ulrich and Eppinger (2007).

In real life the actual work in a product development project is performed by carrying out a number of interrelated tasks at the activity level, or beneath, in the development process. Some authors, like Ulrich and Eppinger (2007), devices a sequence of steps to be performed, and for each step a number of methods or techniques are suggested. Other authors, such as Pahl and Beitz (2007), prefer a somewhat less dogmatic approach, and simply describes the nature of the problem constituting the need for the activity and offer a number of methods and techniques for handling the tasks. In both cases tools are also suggested but presented separately from the actual tasks.

By assuming that each and every task is conducted by utilizing the knowledge emanating from a single discipline, a number of interrelated tasks constitute a platform in solving a problem. Depending on the complexity of a problem to be solved different dependencies among the tasks can be identified. One of the first to discuss such an approach are Wheelwright and Clark (1992). In Eppinger et al. (1994) and Krishnan et al. (1997) the following dependencies between tasks are identified: *sequential tasks, overlapping sequential tasks, parallel tasks,* and *coupled tasks*.

The sequence of the tasks as well as the nature of each task depends on the problem to be solved, which in turn emanate from the actual application. Thus, a given sequence of tasks requires specific knowledge. By introducing new methods, techniques and/or tools will result in a new set of tasks as well as the sequence of the tasks in solving the problem. This may result that additional or less knowledge might be required. On the other hand if the actual problem is changed due to changes in the application this results in changes of the set of task, the sequence of tasks, the methods, the techniques, and the tools, and thus in the knowledge required. By identifying effect(s) related to the packaged product it is possible to redefine the problems constituting the concerned activities in the product development process. This approach enables the actual integration of package development into the product development.

One method developed to identify this type of effect(s) is *the gallery technique* (Olesen, 1992) based on Olesen's theory (1996) on *dispositions*. According to Olesen (1992) it is important to incorporate knowledge on the product life cycle in product development. He state that there exist interfaces between artefacts and activities in the product lifecycle, also denoted *dispositions*.

Dispositions occur in inter-functional relationships, where one decision in one functional area affects different activities in other functional areas. Looking at the different phases/systems of a product's lifecycle, from development and onwards, dispositional effects occur all along the lifecycle and should be taken into account, be controlled and exploited. They are measured "in terms of their effects on the universal virtues", i.e. on cost, quality, flexibility, risk, speed, efficiency, environmental effects (Olesen et al., 1996). Olesen et al. (1996) provide *a gallery technique* analyze dispositions in the product life cycle, knowledge to consider during the development process. Figure 3.9 illustrates dispositional effect and the gallery technique.

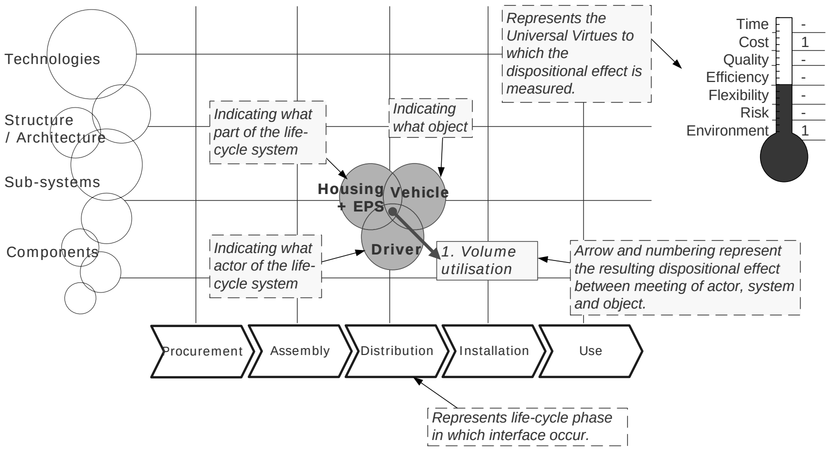

Figure 3.9 Example illustrating the gallery technique used in case analysis.

3.4 Research standpoint

According to the theories provided and discussed above, there are discrepancies between current product development theory and package development theory.

Furthermore, there is no theory discussing *integration,* or any other combining, of two development processes - such as addressed in the concept for Integrated Product and Package Development.

4 Synthesis of results and appended papers

The term synthesis *is commonly understood as the merging of two or more pre-existing elements which results in a new creation. The following chapter synthesises the results of this thesis by connecting the individual contributions of the appended papers. This approach allows the author to comment on already published contributions in a fashion equivalent to a monograph.*

4.1 Prologue

As previously stated, this thesis encompasses seven studies – see Figure 2.1. In each of these studies results obtained have been presented in one or more publications. Here only the core results necessary for answering the research questions (see section 1.3) are included in the form of appended papers.

In other words, by presenting the core results and how they are related to each other, the results necessary for answering the research questions are obtained, thus in the end fulfilling the overall objective (see section 1.4). To operationalise the process of fulfilling this overall objective, it has been decomposed into four sub-objectives (see section 1.4).

In this chapter the goal is to elaborate on each and every one of these studies, and in turn how they are interrelated. The presentation of the studies follows the sequence in which they were performed as well as the decomposition of results into theoretical and empirical results (see Figure 2.1). Note that by presenting each and every study, not only the core results as given in the appended papers but also the additional results/publications will be included. Thus providing an extensive insight into the actual research work performed within each study.

4.2 Study 1

The goal of this study is to perform a review of related work for the concept of integrating product and package development.

The *result of this literature review* was based on the publication which triggered this research project, i.e. Bjärnemo, Jönson and Johnsson

(2000). The findings of the literature review are presented in Bramklev (2000). These findings do not represent core findings in the given context.

4.3 Study 2

The goal of study 2 was to explore and describe the real industrial support for introducing an integrated product and package process in the mechanical industry.

The findings obtained during study 1 provide an important starting point for this study, as no integrated approach has been previously identified.

The *findings from the literature* review provided extensive knowledge on the different development process models existing within mechanical engineering, and thus provided the necessary theoretical foundation upon which the subsequent survey questionnaire forms were established.

The *main empirical result* contributing to answering RQ 1 was the extensive support of and interest in the proposed integration concept. Additional empirical results on the support of the integration of product and package development are the considerations and measures taken, in a considerable number of the companies, on the interaction of the product and the package, thus indicating an *emerging* awareness of the problem area. For example, company A recognized the importance for the package design to complement the product design based on experiences from distribution failures when introducing one of their products on the international market.

With respect to RQ 2, it was found that in almost all companies the package is developed during the product development process. Furthermore, in a majority of the companies the package was specified during the product development process. However, there were no specialists for package design and development identified within the product development organization.

The findings from this study constitute the core results reported in *appended paper I (Bramklev, Bjärnemo & Jönson, 2001)*.

4.4 Study 3

The goal of study 3 was to explore and describe the tangible industrial support for introducing an integrated product and package development process in the pharmaceutical product industry and the food product industry.

The findings obtained during study 2 provide an important starting point for this study, as it will be interesting to compare studies afterwards.

The *findings from the literature* review provided extensive knowledge on the different development process models existing within the pharmaceutical and food product areas, and also contributed to the necessary theoretical foundation upon which the subsequent survey questionnaire forms were established.

In this review it was found that the concept of integrating product and package was already acknowledged, especially when it comes to integrating the primary package into the product development process. This new information contributes to answering RQ1. Note that this new information was lacking in study 1.

With reference to RQ 2, the literature review on packaging technology showed that the package functions are specified based on the purpose of the package relative to the product.

Furthermore, literature on the food product area states that the specification of the package and the packaging system is performed during the food development process – see Blanchfield (1988) and Jónsdóttir (1998).

For the pharmaceutical product area, literature states the dependency between package design and the production process, indicating the importance of considering such aspects during the product development process – see e.g. Pisano (1996). Results from literature also note that pharmaceutical product development needs to be more engaged in alternative formulations and delivery systems, where the package might provide features for alternative delivery systems — see Ratti & Trist (2001).

The main *empirical result* contributing to answering RQ 1 was, also here, the extensive support of and interest in the proposed integration concept. As for study 2, additional empirical results on the support of the integration of product and package development are the considerations and measures taken, in a considerable number of the companies, on the interaction of the product and the package, thus indicating an awareness of the problem area.

With respect to RQ 2, it was found that in almost all companies the package is developed during the product development process. Furthermore, in a majority of the companies the package was specified during the product development process. This study identified specialists for package design and development within the product development organization.

The findings from this study form the core results reported in *appended paper II (Bramklev, Bjärnemo & Jönson, 2004b)*.

4.5 Synthesis of studies 1, 2 and 3

An important stepping stone after finishing study three was the synthesis of studies 1, 2 and 3, which resulted in a licentiate of engineering thesis (see Bramklev, 2004) in which a first attempt to develop an integrated product and package development model was made. This model was separately solely reported as a technical paper (Bramklev, Bjärnemo & Jönson, 2004a) and published in Bramklev (2004). These studies also acknowledge the importance of investigating the package manufacturer's perspective on the proposed integration concept.

The synthesis of survey findings and acknowledgements on using a survey method are also discussed in an article by Bramklev (2007d). Here it is acknowledged that for the establishment of Integrated Product and Package Development (IPPkgD) in industry, it is necessary to further investigate 1) *what* life cycle aspects a packaged product should possess in order to achieve an efficient and effective design, 2) *how* one should manage, control and execute product and/or package development and 3) *why* one should implement the concept in industry.

4.6 Study 4

The goal of study 4 was to explore the interest of the package manufacturing industry in the proposed integration concept, but more importantly to explore and describe the package development process used within industry.

The findings obtained during studies 1, 2 and 3 provide important inputs into this study, especially those indicating discrepancies between theoretical descriptions of the package development process.

Based on *findings from the literature* review on the different development process models existing for package development, the case study topics were formed and questionnaires designed.

The main *empirical result* contributing to answering RQ 1 was the support of and interest in the proposed integration concept. An additional empirical result on the support of the integration of product and package development was, from the package manufacturers perspective, a wish to smooth interaction with product manufacturers, thus facilitating early knowledge transfer on the package to product manufacturer.

With respect to RQ 2, a discrepancy is found between theory and practice in the package development process. Additional results identified aspects for which product and package manufacturer interacted. These aspects concerned both *what* was important in the interaction, and *when* interaction was performed, which also stresses the magnitude of the integration problem between the product and package development processes.

The findings of this study are reported in the technical case report on package development (Bramklev, 2007c).

Together with the results from studies 1, 2, and 3, the results of this pilot case study are utilized in developing a preliminary integrated product and package development model. This model forms the core results of this study and is reported in *appended paper III (Bramklev et al., 2005).*

4.7 Study 5

The goal of study 5 was to establish the industrial support for introducing an integrated product and package development process within the package manufacturing industry, as well as to describe current practice in the package development process, and if necessary update package development process theory for facilitating its integration into the product development process.

The findings obtained during study 4 provide an important starting point, as they indicate the importance of a deeper understanding of current package development practice, as well as the existence of a discrepancy between theory and practice.

The *findings from the literature* review provided support for integrating product and package development, and thus provided additional findings for answering RQ1.

Furthermore, the literature review provided insights into the current package development process models. These findings represent essential contributions for answering RQ 2. It should be noted that these findings contribute to a redefinition of the terms "package" and "packaging". Up to this point the term *packaging* was used for both the package (as an object) and the processes associated with the actual use of the package. In order to emphasize the physical nature of the actual package discussed, the term *packaging* was forsaken in favour for the term *package*.

The *main empirical result* contributing to answering RQ 1 was the support of integrating product and package development within the package manufacturing industry. However, it should be noted that in spite of this awareness very few measures are taken in order to accommodate this integration.

Additional results contributing to the answering of RQ 2 were those emanating from the descriptions of the package development processes in practice. These descriptions contributed additional results on a magnitude of aspects for *what* was integrated (or not) and *when* integration occurred (or not) between product and package manufacturers.

In retrospect, study 5 could have focused on providing a somewhat deeper insight into the actual activities occurring during the conceptualization of the PPS during the product development process.

A summary of the literature findings is reported in a technical report on packaging technology (Bramklev, 2007a), and in a technical report covering studies 4 and 5 (see Bramklev, 2007c).

The findings from study 5 form the core results reported in *appended paper IV (Bramklev, 2007e)*.

4.8 Study 6

The goal of study 6 was to explore and describe the concept of integration between development processes.

The findings obtained during all the previous studies provide an important starting point as no integrated approach has been found for the integration of the product development process and the package development process.

The *findings from the literature* review provided extensive knowledge on current integrated product development theory, but none directly applicable to the integration of development processes. However, a number of aspects were found that were analyzed and utilized in a related publication by Bramklev (2007b). Here a conceptual framework for integration in product development literature was developed. Four aspects were found for the establishment of integration in a product development project: *the scope of integration* (*how* integration is established); *the power of integration* (*why* integration is used in a particular setting); *the surface of integration* (*what* is integrated); and *timing of integration* (*when* integration is suitable). These four aspects are established on the strategic, tactical and operational level of the company for each product development project. See Figure 4.1 below.

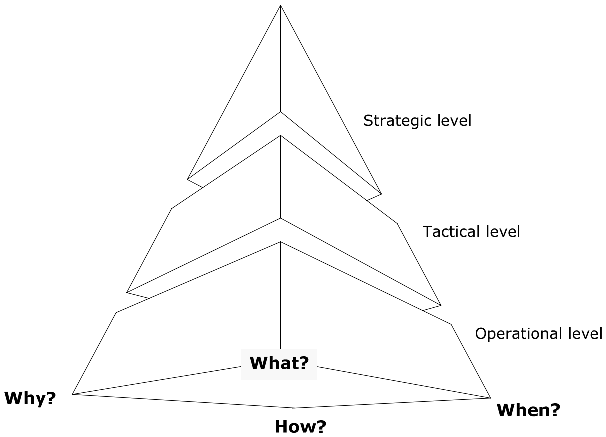

Figure 4.1 A conceptual framework for integration

The conceptual framework might be considered acceptable from a purely theoretical point of view in describing the structuring of the integration phenomena in product development. However, in the given context, the conceptual framework is not facilitating integration on a practical level. The conceptual framework does not provide an answer to how to create the solution - the PPS.

A second attempt at identifying such integration, but now in a lifecycle perspective, was performed and is reported in Motte, Bramklev and Bjärnemo (2007). The concept is still under development and is not implementable in the given context.

A promising contribution found in literature is the theory of dispositions (Olesen, 1992) and the gallery technique for analyzing these dispositions (Olesen et al., 1996). In order to evaluate this approach a test was performed on package and logistics interaction, and reported in Beckeman and Bramklev (2007). Based on a positive outcome of this test, the Olesen theory on dispositions was selected and implemented in an empirical study with the objective to contribute to the development of an integrated product and package design theory.

Within this empirical study, a *main result* contributing to answering RQ 2 is the identification of several aspects of packaged products that should be integrated for the development of the packaged product.

The findings from study 6 form the core results reported in *appended paper V (Bramklev & Hansen, 2007).*

4.9 Study 7

The goal of study 7 was to synthesize, and thus provide, a first version of an integrated product and package development process.

The findings obtained during all previous studies provide the inputs for this study, and thus form the theoretical and empirical foundation upon which the procedure model was developed.

The findings from study 7 form the core results reported in *appended paper VI (Bramklev & Bjärnemo, 2007).*

5 Conclusions and future work

In this chapter the answers to the research questions as well as the fulfilment of the research objectives are elaborated upon. The contributions of the thesis and suggestions for further research derived from it are also provided.

5.1 Concluding remarks on the research questions and the overall research objective

This thesis comprises the seven studies previously described. Each of these studies contributes with results necessary for answering the research questions and thus also, in step by step fashion, to the fulfilment of the sub objectives and thus to the overall objective set out for this thesis work.

With regard to RQ 1 (see Chapter 1.3), the results from studies 1, 2 and 3 form the main body of knowledge necessary for answering this question. However, since these studies are restricted to information retrieved from the product manufacturing industry, more data are needed since the corresponding information from the package manufacturing industry is not included. In studies 4 and 5, especially in study 5, this complementary information is provided.

Regarding fulfilment of sub objective one (see Chapter 1.4), it is clear that the literature reviews during studies 1, 2, 3, 4, and 5 cover the current knowledge on integration of product and package development.

In the literature, support was found for the integration of product and package development in some of the references within the literature on the development of food and pharmaceutical products, while the only reference found within the mechanical products was the one initiating this research project (Bjärnemo, Jönson & Johnsson, 2000).

Since the initiative for integration is decided within the product manufacturing industry, sub objective 2 (see Chapter 1.4) is fully reached within the constraints of the studies performed. It should be noted that there are companies that have included a package development function fully responsible for the complete development of the package, for example IKEA, Hewlett Packard and Philips. However, in none of these companies, to the best knowledge of the present author, is there an integrated product and package development process.

Concluding the answer to RQ 1, the response from the product manufacturing industry as well as from the package manufacturing companies is in strong support of the integration concept.

In answering RQ 2 (see Chapter 1.3), studies 4, 5 and 6 form the supportive body of knowledge necessary, with complementary information from studies 1, 2, and 3. The overall result is provided in study 7.

In addition to a well-established generic product development process, it is also necessary to establish a likewise generic package development process adapted for the intended integration. As such a process was found neither in the literature nor in the case studies, the development of a significantly ”updated” development process was necessary. This proposal fulfils sub objective three (see Chapter 1.4).

In a similar way, the results from study 7, the first version of an integrated product and package development process model, fulfil sub-objective four (see Chapter 1.4). There is significant, though indirect, support of this model through the actual process of developing it, as reported in studies 1-6. One uncertainty in this model is the extent to which it is operational in its current version. This is the inevitable outcome of the necessity to constrain this research thesis project.

Concluding the answer regarding RQ 2, the first version of an integrated development process, based on the updated package development process and information available from literature and from the studies, forms the knowledge necessary to answer this question positively.

Fulfilling the sub objectives also fulfils the overall research objective. The positive contribution as expressed in the statement of the overall objective is thus, in the same manner as for the fulfilment of sub objective 4 (see Chapter 1.4), indirectly fulfilled.

5.2 Reflection

The research process gradually resulting in this thesis has been a process consisting of gradual knowledge build-up. As a researcher I think it is important to have a clear vision of what good science means and why it makes a difference, and therefore some reflections are provided below.

5.2.1 Verification

Verification of design research tends to be complicated in comparison to traditional technically-oriented research and research within the natural sciences (Mattiassen, 1997). This is also the case regarding verification of research within product development, which is only to be verified in practise through successful application to practical problems (Olesen, 1992). This is a difficult task due to the inherent uniqueness of each development process and development project, originating in their stochastic nature and a large number of influencing factors that make repetition of the product development process (and generalisation through experiments on it) virtually impossible (see e.g. Browning, Fricke & Negele, 2006; Roozenburg & Eekels, 1995).

Even though Buur (1990) suggests two methods for verifying the validity of design theory, *logical verification* or *verification by acceptance*, Ullman (1992) states that feasibility judgements often are based on "gut-feeling", which is dependent on the design engineers' experience. From a research point of view this is a challenge.

Furthermore, one should also consider the difficulty of implementing (preliminary) research findings in a busy working environment. Verification in the given context as part of a PhD research project is also restricted by too short a timeframe for an appropriate implementation and analysis of the results.

For the reasons accounted for above, no verification of the conventional kind has been carried out. Suggestions for such attempts are provided in the following section.

5.2.2 Generalisation

Generalisation of the results derived in this thesis, like the results of the surveys, case studies and the literature reviews, produces not only general patterns of a prevailing opinion about product and package development activities across product areas, but also widespread and detailed descriptions (Jick, 1979; Yin, 2003). The survey results are also estimated to be as *accurate* as necessary to achieve the objectives set forth in this thesis. The results are also *timely,* as they are available for immediate use and *accessible* to the respondents participating in the studies. Thus, as far as has been possible within the framework of this research project, the results meet the data quality demands.

However, a survey result is especially suitable for generalisation when the sample represents the population, which is the case only for random samples (Biemer & Lyberg, 2003; Malhotra, 1996). As a non-random sampling technique has been used for this research project, generalised recommendations can only be made for those companies participating in the study. Any other use of the recommendations must be implemented and tested before being applied.

5.3 Contribution of the thesis

In this thesis, strong support for integrating two presently separate development processes, the product development process and the package development process, has been identified in theory and in industry.

Subsequently, an initial version of an implementable procedure model for integrating product and package development for discrete, physical and engineered products has been developed. During this development of a procedure model, substantial efforts have been made to identify the mechanisms of integration between development processes, thus contributing to deepening our understanding of integration between such processes.

The potential for decreasing resource utilisation, including costs, and decreasing the "time to market" by an integrated development of product and package is also derived from the results and exemplified.

The thesis also contributes to a more proactive approach in current package development by proposing a package development process model not only well adapted for integration into the product development process, but also providing a more proactive and holistic approach to the development of new and innovative packages for the global market.

Even though survey methods and case methods are common in many research projects, the combination of the two employed here is specifically designed to fit the actual problems occurring in the interrelated development processes. The combination of methods, with the added process modelling technique, has proven to be effective and efficient in studying aspects of integrated development processes, and can thus be recommended for similar projects in the future.

5.4 Further research

As the main contribution of this thesis undoubtedly is the procedure model for the integration of product development and package development, further research activities/projects should take off from this model. A number of suggestions are provided below:

- Before the final, industrially implementable, procedure model is utilised in actual industrial practice, it is necessary to further verify and develop the proposed model. A natural first step would be to investigate the proposed procedure model through a *retrospective case study.* The expected outcome of such a study is the confirmation of the potentials of the model, thus supplying the necessary industrial support for utilising the model in a real development project.
- Utilising the proposed development model in one or more industrial development project(s). The expected outcome will be a clear support or rejection of the model. If reaction to the model were positive, such a study would also provide suggestions for improvements of the model.
- It will be important to further develop the proposed model by extending it to other product areas, such as food and pharmaceuticals.
- Future verification and extensions of the proposed integration concept should also include the development of enabling methods, techniques and tools to be used on an operational level.
- Future research on the concept of integrating product and package development should also be extended to investigate the problem of integration of the model in a *global product development* perspective. This would include describing and solving the obstacles of harmonising global product development in multinational/global companies.
- Furthermore, research adducing statistics regarding the interrelationships between worldwide facilities could provide additional assistance in describing widespread practices and trade patterns, and also prove interesting for opportunities and investments in the package manufacturing industry.

References

[1] Adamsson, N. (2007), *Interdisciplinary integration in complex product development,* PhD Dissertation, Department of Machine Design, Royal Institute of Technology, Sweden.

[2] Allen, C. W. (1989), "Simultaneous engineering: What? Why? How?", in *Proceedings of SME Simultaneous Engineering Conference*.

[3] Andreasen, M. M. & Hein, L. (1987), *Integrated Product Development,* IFS (Publications) Ltd / Springer-Verlag.

[4] Argyris, C. (1992), *On Organizational Learning,* Blackwell, Cambridge, Massachusetts.

[5] Argyris, C. & Schön, D. A. (1991), "Participatory Action Research and Action Science Compared," in *Participatory Action Research*, W. Foote Whyte (Ed), Sage Publications Inc., pp. 85-95.

[6] Ballantyne, D. (2004), "Action research reviewed: a market-oriented approach", *European Journal of Marketing*, vol. 38 (3/4), pp. 321-337.

[7] Beckeman, M. & Bramklev, C. (2007), "Past present and future roles of the package in logistics", Published in the Proceedings of the 19th NOFOMA Conference, 7-8 June, 2000., Reykjavik.

[8] Biemer, P. P. & Lyberg, L. E. (2003), *Introduction to survey quality,* John Wiley & Sons, Hoboken, New Jersey.

[9] Bjärnemo, R., Jönson, G., & Johnsson, M. (2000), "Packaging Logistics in Product Development", J. Singh, S. C. Lew, & R. Gay (Eds), Gintic Institute of Manufacturing Technology, Singapore, pp. 135-146.

[10] Blanchfield, R. (1988), "How the new Food Product is Designed", *Food Science and Technology*, vol. 2 (1), pp. 54-56.

[11] Boisot, M. H. (1998), *Knowledge asets: Securing competitive advantage in the information economy,* Oxford University Press, Oxford.

[12] Bowersox, D. J., Closs, D. J., & Cooper, M. B. (2002), *Supply Chain Logistics Management,* 1st International edn, McGraw - Hill / Irwin, New York.

[13] Boyle, T., Kumar, V., & Kumar, U. (2006), "Determinants of integrated product development diffusion", *R & D management*, vol. 36 (1), pp. 37-54.

[14] Bramklev, Caroline (2007a), *Packaging Technology,* Lund, Department of Design Sciences, Lund University.

[15] Bramklev, C. (2000), "The requirement of an integration model in Packaging Development", in *Proceedings of NOFOMA 2000, June,* NOFOMA, Aarhus.

[16] Bramklev, C. (2007b), *The concept of "Integration",* Department of Design Sciences, Lund University, Lund, Technical paper in report series on Integrated Product and Package Development (submitted to TMCE08).

[17] Bramklev, Caroline (2004), *Concurrent Development of Product and Packaging - Towards an Integrated Development Procedure,* Lund, Department of Design Sciences, Division of Packaging Logistics, Lund University, Sweden.

[18] Bramklev, C. (2007d), *A survey on the concept of integrating Product and Package Development,* Lund University, Department of Design Science, Division of Packaging Logistics, Lund, Technical paper in report series on Integrated Product and Package Development.

[19] Bramklev, C. (2007e), *On a proposal for a Generic Package Development Process,* Department of Design Sciences, Lund University, Lund, Technical report series on Integrated Product and Package Development.

[20] Bramklev, Caroline (2007c), *The Package Development Process,* Lund, Department of Design Sciences at Lund University.

[21] Bramklev, C. & Bjärnemo, R. (2007), *Product and Package Development - an Integrated Approach,* Department of Design Sciences, Lund University, Lund, Technical report series on Integrated Product and Package Development.

[22] Bramklev, C., Bjärnemo, R., & Jönson, G. (2001), "Concurrent Design of Product and Package - Extending the Concept of IPD", in *Proceedings of International Conference on Engineering Design (ICED 01),* Professional Engineering Publishing Limited, Glasgow, pp. 377-384.

[23] Bramklev, C., Bjärnemo, R., & Jönson, G. (2004b), "Increasing competitiveness through concurrent development of product and packaging", in *Proceedings of 5th international symposium on tools and methods of competitive engineering, TMCE2004,* I. Hovárth & P. Xirouchakis (Eds), Millpress, Rotterdam, Netherlands, pp. 855-868.

[24] Bramklev, C., Bjärnemo, R., & Jönson, G. (2004a), *Towards Integration of Product and Packaging Development,* Department of Design Sciences, Lund University, Lund, Technical paper in report series on Integrated Product and Package Development.

[25] Bramklev, C., Bjärnemo, R., Jönson, G., & Johnsson, M. (2005), "Towards an integrated design of product and packaging", in *Proceedings of ICED05, Melbourne, Australia, August,* Design Society.

[26] Bramklev, C. & Hansen, T. C. (2007), "On the logistics effects of integrated product and package design", in *Proceedings of the International Conference on Engineering Design 2007,* Design Society.

[27] Briston, J. H. & Neill, T. J. (1972), *Packaging Management,* Gower Press, Surrey.

[28] Browning, T. R., Fricke, E., & Negele, H. (2006), "Key Concepts in Modelling Product Development Processes", *Systems engineering*, vol. 9 (2), pp. 104-128.

[29] Browning, T. R. & Ramasesh, R. V. (2007), "A Survey of Activity Network-based Process Models for Managing Product Development Projects", *accepted for publication in the journal "Production and Operations Management".*

[30] Buur, J. (1990), *A theoretical approach to mechatronics design,* PhD Dissertation Dissertation, Institute for Engineering Design, TU of Denmark, Lyngby.

[31] Calver, Giles (2004), *What is packaging design?,* Switzerland, Mies, Rotovision.

[32] Clausing, D. (1993), "World-Class Concurrent Engineering," in *Concurrent Engineering: Tools and Technologies for Mechanical Engineering*, vol. 108 Spinger-Verlag, pp. 3-40.

[33] DeMaria, K. (2000), *The Packaging Development Process: A Guide for Engineers and Project Managers,* Technomic Publishing Company, Inc., Lancaster, Pennsylvania, U.S.A.

[34] Dicken, P. (2003), *Global shift: reshaping the global economic map in the 21st century,* 4th ed. edn, Sage, London.

[35] (1994). European Parliament and Council Directive 94/62/EC on packaging and packaging waste, www2.hdm-stuttgart.de/printing-green/D9462.html

[36] Dunning, J. H. (1988), "The eclectic paradigm of international production: a restatement and some possible extensions", *Journal of International Business Studies*, vol. 19 (Spring), pp. 1-31.

[37] Earle, M. D. (1997), "Changes in the food product development process", *Trends in Food Science and Technology*, vol. 8 (1), pp. 19-23.

[38] Earle, M., Earle, R., & Anderson, A. (2001), *Food product development,* CRC Press, Cambridge, England.

[39] Eden, C. & Spender, J.-C. (1998), *Managerial and organization cognition: Theory, methods, and research,* Sage, London.

[40] Ehrlenspiel, K. (1991), *Integrierte Produkterstellung. Organisation-Method-Hilfsmittel,* IWB Institut fur Werkzeugmaschinen und Betriebswissenschaften, TU, Munchen.

[41] Eisenhardt, K. M. (1989), "Building Theories from Case Study Research", *Academy of Management Review*, vol. 14 (4), pp. 532-550.

[42] Eppinger, S. D., Whitney, D. E., Smith, R. P., & Gebala, D. A. (1994), "A Model-Based Method for Organizing Tasks in Product Development", *Research in Engineering Design*, vol. 6 pp. 1-13.

[43] Esse, Robert L. (1989), *Package Development, Manufacturing, and Distribution Strategy Considerations,* Lancaster, Technomic Publishing Company Inc.

[44] Evans, B. (1988), "Simultaneous Engineering", *Mechanical Engineering*, vol. 110 (2), pp. 38-40.

[45] Eversheim, W., Bochtler, W., Grässler, R., & Kölscheid, W. (1997), "Simultaneous engineering approach to an

integrated design and process planning", *European Journal of Operational Research*, vol. 100 pp. 327-337.

[46] Finger, S. & Dixon, J. R. (1998), "A Review of Research in Mechanical Engineering Design. Part I: Descriptive, Prescriptive, and Computer-Based Models of Design Processes", *Research in Engineering Design*, vol. 1 pp. 51-67.

[47] Finkenzeller, K. (2003), *RFID HANDBOOK: Fundamentals and Applications in Contactless Smart Cards and Identification,* 2nd edn, WILEY.

[48] Firestone, W. A. (1987), "Meaning in method: the rhetoric of quantitative and qualitative research", *Educational Researcher*, vol. 16 (7), pp. 16-21.

[49] French, M. J. (1985), *Conceptual Design for Engineers,* 2nd edn, Design Council, London.

[50] Fuller, G. W. (2005), *New Food Product Development - From concept to marketplace,* 2nd edn, CRC Press, London.

[51] Gerwin, D. & Barrowman, N. J. (2002), "An evaluation of research on Integrated Product Development", *Management Science*, vol. 48 (7), pp. 938-953.

[52] Giles, G. A. (2000), *Design and Technology of Packaging Decoration for the Consumer Market,* CRS Press, Sheffield Academic Press, Sheffield.

[53] Glaser, B. G. & Strauss, A. L. (1967), *The Discovery of Grounded Theory - Strategies for Qualitative Research,* Aldine Publishing Company, Chicago.

[54] Goldstein, G. (1989), "Integrating Product and Process Design", *Mechanical Engineering*, vol. 111 (4), pp. 48-51.

[55] Graf, E. & Saguy, I. S. (1991), *Food Product Development,* Chapman & Hall, London.

[56] Griffin, A. (1997), "PDMA Research on New Product Development Practices: Updating Trends and Benchmarking Best Practices", *Journal of Product Innovation Management*, vol. 14 (6), pp. 429-458.

[57] Griffin, A. & Hauser, J. R. (1996), "Integrating R&D and Marketing: A Review Analysis of the Literature", *Journal of Product Innovation Management*, vol. 13 pp. 191-215.

[58] Griffin, R. C. Jr., Sacharow, S., & Brody, A. L. (1985), *Principles of Package Development,* 2nd edn, Van Nostrand Reinhold Company, New York, USA.

[59] Hammer, M. (2001), "Seven insights about processes", in *In proceedings of the conference: The Strategic Power of Process: From Ensuring Survival to Creating Competitive Advantage,* Boston, Mar 5-6.

[60] Hanlon, J. F., Kelsey, R. J., & Forcinio, H. E. (1998), *Handbook of Package Engineering,* 3rd edn, CRC Press, London.

[61] Harckham, Arthur W. (1989), *Packaging Strategy Meeting the Challenge of Changing Times,* Pennsylvania USA, Technomic Publishing Inc.

[62] Hart, C. (1998), *Doing a Literature Review - Releasing the Social Science Research Imagination,* Sage Publications Ltd, New York.

[63] Hein, L., Pedersen, F. M., Andreasen, M. M., & Olsson, F. (1984), "Integrated product development: new potential products", in *Proceedings of the International Conference of Desing Policy,* R. Langdon (Ed), The Design Council, London, pp. 86-90.

[64] Hovárth, Imre (2004), "A treatise on order in engineering design researh", *Research in Engineering Design,* vol. 15 155-181.

[65] Huang, G. Q. (1996), *Design for X - Concurrent Engineering Imperatives,* 1st edn, Chapman & Hall, London, UK.

[66] Huang, H.-Z. & Gu, Y.-K. (2006), "Development mode based on integration of product models and process models", *Concurrent Engineering: Research and Application*, vol. 14 (1), pp. 27-34.

[67] Hubka, V. (1989), *Principles of Engineering Design,* Springer, New York.

[68] Jick, T. D. (1979), "Mixing Qualitative and Quantitative Methods: Triangulation in Action", *Administrative Science Quarterly*, vol. 24 (December), pp. 602-611.

[69] Johansson, K. & Weström, P. Optimum division of critical properties between primary, secondary and tertiary packaging. 2000. Kista, Packforsk.
Ref Type: Pamphlet

[70] Jónsdottir, S., Vesterager, J., & Börresen, T. (1998), "Concurrent Engineering and Product Models in Seafood Companies", *Trends in Food Science and Technology* (9), pp. 362-367.

[71] Jönson, G. (2000), *Packaging Technology for the Logistician,* 2nd edn, Department of Design Sciences, Packaging Logistics, Lund University, Lund.

[72] Judd, David, Aalder, Bert, and Melis, Theo C. J. M. (1989), *The Silent Salesman: Primer on Design, Production and Marketing of Finished Packaged Goods,* Singapore, Octogram.

[73] Kinnear, T. C. & Taylor, J. R. (1996), *Marketing Research - an Applied Approach,* 5th edn, New York.

[74] Kolb, D. A. (1984), *Experiential Learning: Experiences as a Source of Learning and Development,* Prentice-Hall, Englewood-Cliffs, N.J.

[75] Kooijman, J. M. (1995), *The Environmental Impact of Packaging - Performance in the Food Supply Chain,* London, Incpen.

[76] Kotler, P. (1980), *Marketing Management, Analysis, Planning and Control,* Prentice-Hall, New Jersey, USA.

[77] Kotler, P. & Armstrong, G. (1994), *Principles of Marketing,* 6th edn, Englewood Cliffs, New Jersey.

[78] Krishnan, V., Eppinger, S. D., & Whitney, D. E. (1997), "A Model-Based Framwork to Overlap Product Development Activities", *Management Science*, vol. 43 pp. 437-451.

[79] Krishnan, V. & Ulrich, K. T. (2001), "Product Development Decisions: A Review of the Literature", *Management Science*, vol. 47 (1), pp. 1-21.

[80] Lambert, D. M., Stock, J. R., & Ellram, L. (1998), *Fundametals of Logistics Management,* McGraw-Hill.

[81] LaSala, K. P. (1990), "AFSC Integrated Product Development", in *Proceedings of R&M CAE in Concurrent Engineering Workshop,* pp. 23-30.

[82] Lee, S. G. & Lye, S. W. (2003), "Design for manual packaging", *International Journal of Physical Distribution & Logistics Management*, vol. 33 (2), pp. 163-189.

[83] Leedy, P. D. (1997), *Practical Research - Planning and Design,* 6th edn, Upper Saddle River, New Jersey.

[84] Ljungberg, A. & Larsson, E. (2001), *Processbaserad verksamhetsutveckling,* Studentlitteratur, Lund.

[85] Lombardino, J. G. & Lowe III, J. A. (2004a), "The role of the medicinal chemist in drug discovery - then and now", *Nature Reviews*, vol. 3 (October), pp. 853-862.

[86] Lombardino, J. G. & Lowe III, J. A. (2004b), "The role of the medicinal chemist in drug discovery - then and now", *Nature reviews*, vol. 3 (October), pp. 853-862.

[87] Lye, S. W. & Ho, H. K. (1994), "An integrated framework for protective packaging design and manufacture", *International Journal of Production Research*, vol. 32 (8), pp. 1837-1856.

[88] Malhotra, N. K. (1996), *Marketing research - an Applied Orientation,* Prentice-Hall International Limited, London.

[89] Matin, A. & Evans, S. (1992), "Project planning in a concurrent engineering environment", *IEEE* pp. 298-303.

[90] Mattiassen, B. (1997), *Design for Robustness and Reliability - Improving the Quality Consciousness in Engineering Design,* PhD Dissertation Dissertation, Department of Control and Engineering Design, TU of Denmark, Lyngby.

[91] McClintock, C. C., Brannon, D., & Maynard-Moody, S. (1979), "Applying the Logic of Sample Surveys to Qualitative Case Studies: The Case Cluster Method", *Administrative Science Quarterly*, vol. 24 (December), pp. 612-629.

[92] Melan, E. H. (1993), *Process Management: Methods for Improving Products and Service,* McGraw-Hill, New York.

[93] Melis, T. (1991), *The Innovative Packager, Planned Innovation and Problem-Solving in Packaging Development,* Octogram, Singapore.

[94] Meyer, R. S. (1984), "Eleven Stages of Successful New Product Development", *Food Technology*, vol. 38 (July), pp. 71-78, 98.

[95] Miles, M. B. & Huberman, A. M. (1994), *Qualitative Data Analysis - An Expanded Sourcebook.,* 2nd edn, Sage, Thousand Oaks, CA.

[96] Moskowitz, H. R., Porretta, S., & Silcher, M. (2005), *Concept Research in Food Product Design and Development,* 1st edn, Blackwell Publishing, Oxford, UK.

[97] Motte, D., Bramklev, C., & Bjärnemo, R. (2007), "A method for supporting the integration of packaging development into product development", in *Published in 14th CIRP International Conference on Life Cycle Engineering*.

[98] Negele, H., Fricke, E., & Igensberg, E. (1997), "ZOPH - a systematic approach to the modeling of product development systems", Los Angeles, pp. 773-780.

[99] Nielsen, T. (1997), *Active Packaging - a Literature Review,* The Swedish Institute for Food and Biotechnology, SIK Report 1997 no 631.

[100] Nonaka, I. & Nishigushi, T. (1999), *Knowledge Emergence,* Oxford University Press, New York.

[101] Olesen, J. (1992), *Concurrent development in manufacturing - based on dispositional mechanism,* PhD, Institute for Engineering Design at DTU.

[102] Olesen, Jesper, Wenzel, Henrik, Hein, Lars, and Andreasen, M. Myrup (1996), *Miljöriktig konstruktion,* Copenhagen, Miljö- og Energiministeriet, Miljöstyrelsen.

[103] Olsson, F., Carlqvist, O., & Granbom, H. (1985), *Integrerad produktutveckling - arbetsmodell,* Sveriges Mekanförbund, Stockholm, 85208.

[104] Packforsk. Fakta om förpackningar och miljö. 2001. www.packforsk.se, Stiftelsen Packforsk.
Ref Type: Pamphlet

[105] Pahl, G. & Beitz, W. (1996), *Engineering Design - A Systematic Approach,* 1st edn, Springer-Verlag London Limited, London.

[106] Pahl, G. & Beitz, W. (1984), "The design process," in *Engineering Design; A Systematic Approach*, 2nd edn, K. Wallace (Ed), Springer, Berlin.

[107] Pahl, G., Beitz, W., Feldhusen, J., & Grote, K. H. (2007), *Engineering Design - A Systematic Approach,* 3rd edn, Springer London, London.

[108] Paine, F. A. (1990), *Packaging Design and Performance,* 1st edn, Pira, Surrey.

[109] Pall, G. A. (1999), *The Process-Centered Enterprise: The Power of Commitments,* St. Lucie Press, New York.

[110] Pisano, G. P. (1996), "Learning-before-doing in the development of new process technology", *Research Policy*, vol. 25 (7), pp. 1097-1119.

[111] Porter, M. E. (1998), *The Competitive Advantage of Nations,* Macmillan Press Ltd, London.

[112] Prasad, B. (1996), *Concurrent Engineering Fundamentals,* Prentice Hall, New Jersey.

[113] Prasad, G. V. & Madhusudan, R. B. (2004), "Concurrent engineering in a pharmaceutical firm: a case study of Dr. Reddy's Laboratories Ltd.", *International Journal of Manufacturing Technology and Management*, vol. 6 (3-4), pp. 280-290.

[114] Ratti, E. & Trist, D. (2001), "The continuing evolution of the drug discovery process in the pharmaceutical industry", *Il Farmaco*, vol. 56 (1-2), pp. 13-19.

[115] Rooney, E. M. (1995), *Active Food Packaging,* Chapman & Hall, Glasgow.

[116] Roozenburg, N. F. M. & Eekels, J. (1995), *Product Design: Fundamentals and Methods,* 1st edn, John Wiley & Sons, Inc.

[117] Rudolph & Marvin, J. (1995), "The food product development process", *British Food Journal*, vol. 97 (3), pp. 3-11.

[118] Ruggles, R. (1997), *Knowledge Management Tools,* Butterworth Heinemann, Boston.

[119] Smith, R. P. & Morrow, J. A. (1999), "Product development process modeling", *Design Studies*, vol. 20 pp. 237-261.

[120] Sohlenius, G. (1992), "Concurrent Engineering", *Annals of the CIRP*, vol. 41 (2), pp. 645-655.

[121] Somchai, C., Lye, S.-W., & Yeong, H.-Y. (2000), "An integrated design approach for protective packaging", *Integrated Manufacturing Systems* pp. 321-330.

[122] Sonsino, S. (1990), *Package Design: Graphics, Materials, Technology,* Thames and Hudson, London.

[123] Soroka, W. (1997), *Fundamental of Packaging Technology,* UK Ed. edn, Institute of Packaging, Newcastle upon Tyne.

[124] Sparrow, J. (1998), *Knowledge in Organisation,* Sage, London.

[125] Spilker, B. (1994), *Multinational Pharmaceutical Companies - Principles and Practice,* 2nd edn, Raven Press, Ltd., New York.

[126] Sterling (1982), *Package Development*.

[127] ten Klooster, R. (2002), *Packaging Design: a Methodological Development and Simulation of the Design Process,* Doctoral Dissertation, Delft University of Technology.

[128] Thomke, S., Hippel, E. v., & Franke, R. (1998), "Modes of experimentation: an innovation process - and competitive - variable", *Research Policy*, vol. 27 (3), pp. 315-332.

[129] Thorén, A. & Vinberg, B. (2000), *Pocket book of Packaging,* Sörmlands Grafiska AB.

[130] Trygg, L. (1997), "Concurrent engineering practises in selected Swedish companies: a movement or an activity of few?", *Journal of Product Innovation Management*, vol. 10 (5), pp. 403-415.

[131] Ullman, D. G. (1992), *The Mechanical Design Process,* 2nd edn, McGraw-Hill International, Singapore.

[132] Ulrich, K. T. & Eppinger, S. D. (2007), *Product Design and Development,* 4th edn, McGraw-Hill Companies, Inc., Boston.

[133] Ulrich, K. T. & Eppinger, S. D. (2003), *Product Design and Development,* third edn, McGraw-Hill Companies, Inc., Boston.

[134] Unger, D. & Eppinger, S. D. (2002), "Product Development Process Design: Planning Design Iterations for Effective Product development", in *working paper at MIT Center for Innovation in Product Development*.

[135] Vajna, S. & Burchardt, C. (2000), "Dynamic development structures of Integrated Product Development", in *IPD workshop,* Lehrstuhl fur Maschinenbauinformatik, Magdeburg.

[136] Vernon, R. (1966), "International Investment and International Trade in the Product Cycle", *Quarterly Journal of Economics* (80), pp. 190-207.

[137] Wheelwright, S. C. & Clark, K. B. (1992), *Revolutionizing Product Development - Quantum Leaps in Speed, Efficiency, and Quality,* 1st edn, The Free Press, New York.

[138] Wiig, K. (1995), *Knowledge Management Methods,* Schema Press, Arlington, VA.

[139] Winner, R. I., Pennell, J. P., Bertrand, H. E., & Slusarezuk, M. M. G. (1988), *The Role of Concurrent Engineering in Weapons System Acquisition,* Institute of Defense Analyses, Alexandria, VA, IDA Report R-338.

[140] Yin, R. K. (2003), *Case Study Research: Design and Methods,* 3rd edn, Sage Publications, California.

Appended papers

The following section includes the appended papers for this doctoral dissertation.

Division of Packaging Logistics, Lund University

The following text is a list of publications for doctoral dissertations and licentiate theses for the Division of Packaging Logistics, Department of Design Sciences at Lund University

Hahn K, 1991, A study of the compressive behaviour of corrugated board panels. Licentiate thesis.

Renman M, 1994, A mechanical characterization of creased zones of corrugated board. Licentiate thesis.

Borglin J, 1995, Development of a decision support system for the selection process of corrugated packaging. Licentiate thesis.

Patel P, 1996, Biaxial failure of corrugated board. Licentiate thesis.

Aquilon M, 1997, Cultural factors in logistics management. Licentiate thesis.

Henriksson L, 1998, Packaging requirements in the Swedish retail trade. Licentiate thesis.

Johnsson, M, 1998, Packaging logistics – a value added approach. PhD dissertation.

Patel P, 1999, Nonlinear creep model of paper and corrugated board materials. PhD dissertation.

Persson E, 1999, Creating a competitive advantage in the corrugated board industry. Licentiate thesis.

Berglund A, 1999, Incorporating environmental aspects in transport purchasing. Licentiate thesis.

Bergström P, 2000, A strategic view on relationship in the grocery supply chain – the case of a low complex product. Licentiate thesis.

Saghir M, 2002, Packaging logistics evaluation in the Swedish retail supply chain. Licentiate thesis.

Olsson A, 2002, The integration of customer needs in e-business systems. Licentiate thesis.

Wallin C, 2003, Contract packaging and its implications for the supply chain – a case study of a contract packager. Licentiate thesis.

Nilsson F, 2003, A complex adaptive systems approach on logistics – implications from adopting a complexity perspective. Licentiate thesis.

Abukhader SM, 2003, The environmental implications of electronic commerce – the assessment approach problem. Licentiate thesis.

Orremo F, 2003, E-business in an established customer vendor relationship. Licentiate thesis.

Hellström D, 2004, Exploring the potential of using radio frequency identification technology in retail supply chains. Licentiate thesis.

Bramklev C, 2004, Concurrent development of product and packaging – towards an integrated development procedure. Licentiate thesis.

Saghir M, 2004, A platform for packaging logistics development: a systems approach. PhD dissertation.

Klevås J, 2005, On opportunities of integrated packaging, logistics and product development – experiences from a case study at IKEA. Licentiate thesis.

Gustafsson K, 2005, The process of creating a nation-wide pool system for transport packaging – from vision to decision. Licentiate thesis.

Abukhader SM, 2005, Towards horizontal environmental assessment for supply chain and logistics management. PhD dissertation.

Nilsson F, 2005, Adaptive logistics – using complexity theory to facilitate increased effectiveness. PhD dissertation.

Olsson A, 2006, The change from feature focus to customer focus in packaging development. PhD dissertation.

Johansson O, 2006, Towards a model for managing uncertainty in logistics operations – a simulation modelling perspective. Licentiate thesis.

Dominic C, 2006, Packaging Networks - a framework for integrating packaging suppliers in the Demand Chain. Licentiate thesis.

Beckeman M, 2006, The rise of the Swedish food sector after WW II. What, why, how and who? Licentiate thesis.

Svanberg J, 2006, A constructive approach to the interaction between risk and logistics. PhD dissertation.

Påhlsson H, 2006, Interorganizational collaboration in the context of introducing new technology. Licentiate thesis.

Hellström D, 2007, On interactions between Packaging and Logistics – Exploring implications of technological developments. PhD dissertation.

Lareke, A, 2007, Tyrannical consumers – initiate value creation in the food value chain. Licentiate thesis.