Design of clothing manufacturing processes

The Textile Institute and Woodhead Publishing

The Textile Institute is a unique organisation in textiles, clothing and footwear. Incorporated in England by a Royal Charter granted in 1925, the Institute has individual and corporate members in over 90 countries. The aim of the Institute is to facilitate learning, recognise achievement, reward excellence and disseminate information within the global textiles, clothing and footwear industries.

Historically, The Textile Institute has published books of interest to its members and the textile industry. To maintain this policy, the Institute has entered into partnership with Woodhead Publishing Limited to ensure that Institute members and the textile industry continue to have access to high calibre titles on textile science and technology.

Most Woodhead titles on textiles are now published in collaboration with The Textile Institute. Through this arrangement, the Institute provides an Editorial Board which advises Woodhead on appropriate titles for future publication and suggests possible editors and authors for these books. Each book published under this arrangement carries the Institute's logo.

Woodhead books published in collaboration with The Textile Institute are offered to Textile Institute members at a substantial discount. These books, together with those published by The Textile Institute that are still in print, are offered on the Woodhead web site at: www.woodheadpublishing.com. Textile Institute books still in print are also available directly from the Institute's website at: www.textileinstitutebooks.com

A list of Woodhead books on textiles science and technology, most of which have been published in collaboration with the Textile Institute, can be found towards the end of the contents pages.

We are always happy to receive suggestions for new books from potential editors. To enquire about contributing to our Textiles series, please send your name, contact address and details of the topic/s you are interested in to sarah.lynch@woodheadpublishing.com. We look forward to hearing from you.

The team responsible for publishing this book

Commissioning Editor: Kathryn Picking
Editorial and Production Manager: Mary Campbell
Production Editor: Richard Fairclough
Project Manager: Newgen Knowledge Works Pvt Ltd
Copy-editor: Newgen Knowledge Works Pvt Ltd
Proofreader: Newgen Knowledge Works Pvt Ltd
Cover Designer: Terry Callanan

Woodhead Publishing Series in Textiles: Number 147

Design of clothing manufacturing processes

A systematic approach to planning, scheduling and control

Jelka Geršak

The Textile Institute

WP
WOODHEAD PUBLISHING

Oxford Cambridge Philadelphia New Delhi

Published by Woodhead Publishing Limited in association with The Textile Institute
Woodhead Publishing Limited, 80 High Street, Sawston, Cambridge CB22 3HJ, UK
www.woodheadpublishing.com
www.woodheadpublishingonline.com

Woodhead Publishing, 1518 Walnut Street, Suite 1100, Philadelphia,
PA 19102–3406, USA

Woodhead Publishing India Private Limited, 303, Vardaan House, 7/28 Ansari Road,
Daryaganj, New Delhi – 110002, India
www.woodheadpublishingindia.com

First published 2013, Woodhead Publishing Limited

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library.

Library of Congress Control Number: 2013938663

ISBN 978-0-85709-778-1 (print)
ISBN 978-0-85709-783-5 (online)
ISSN 2042-0803 Woodhead Publishing Series in Textiles (print)
ISSN 2042-0811 Woodhead Publishing Series in Textiles (online)

The publishers' policy is to use permanent paper from mills that operate a sustainable forestry policy, and which has been manufactured from pulp which is processed using acid-free and elemental chlorine-free practices. Furthermore, the publishers ensure that the text paper and cover board used have met acceptable environmental accreditation standards.

Typeset by Newgen Knowledge Works Pvt Ltd, India
Printed by Lightning Source

Contents

Woodhead Publishing Series in Textiles

1 **Watson's textile design and colour Seventh edition**
Edited by Z. Grosicki
2 **Watson's advanced textile design**
Edited by Z. Grosicki
3 **Weaving Second edition**
P. R. Lord and M. H. Mohamed
4 **Handbook of textile fibres Volume 1: Natural fibres**
J. Gordon Cook
5 **Handbook of textile fibres Volume 2: Man-made fibres**
J. Gordon Cook
6 **Recycling textile and plastic waste**
Edited by A. R. Horrocks
7 **New fibers Second edition**
T. Hongu and G. O. Phillips
8 **Atlas of fibre fracture and damage to textiles Second edition**
J. W. S. Hearle, B. Lomas and W. D. Cooke
9 **Ecotextile '98**
Edited by A. R. Horrocks
10 **Physical testing of textiles**
B. P. Saville
11 **Geometric symmetry in patterns and tilings**
C. E. Horne
12 **Handbook of technical textiles**
Edited by A. R. Horrocks and S. C. Anand
13 **Textiles in automotive engineering**
W. Fung and J. M. Hardcastle
14 **Handbook of textile design**
J. Wilson
15 **High-performance fibres**
Edited by J. W. S. Hearle
16 **Knitting technology Third edition**
D. J. Spencer
17 **Medical textiles**
Edited by S. C. Anand
18 **Regenerated cellulose fibres**
Edited by C. Woodings
19 **Silk, mohair, cashmere and other luxury fibres**
Edited by R. R. Franck
20 **Smart fibres, fabrics and clothing**
Edited by X. M. Tao
21 **Yarn texturing technology**
J. W. S. Hearle, L. Hollick and D. K. Wilson
22 **Encyclopedia of textile finishing**
H-K. Rouette
23 **Coated and laminated textiles**
W. Fung

24 **Fancy yarns**
R. H. Gong and R. M. Wright
25 **Wool: Science and technology**
Edited by W. S. Simpson and G. Crawshaw
26 **Dictionary of textile finishing**
H-K. Rouette
27 **Environmental impact of textiles**
K. Slater
28 **Handbook of yarn production**
P. R. Lord
29 **Textile processing with enzymes**
Edited by A. Cavaco-Paulo and G. Gübitz
30 **The China and Hong Kong denim industry**
Y. Li, L. Yao and K. W. Yeung
31 **The World Trade Organization and international denim trading**
Y. Li, Y. Shen, L. Yao and E. Newton
32 **Chemical finishing of textiles**
W. D. Schindler and P. J. Hauser
33 **Clothing appearance and fit**
J. Fan, W. Yu and L. Hunter
34 **Handbook of fibre rope technology**
H. A. McKenna, J. W. S. Hearle and N. O'Hear
35 **Structure and mechanics of woven fabrics**
J. Hu
36 **Synthetic fibres: nylon, polyester, acrylic, polyolefin**
Edited by J. E. McIntyre
37 **Woollen and worsted woven fabric design**
E. G. Gilligan
38 **Analytical electrochemistry in textiles**
P. Westbroek, G. Priniotakis and P. Kiekens
39 **Bast and other plant fibres**
R. R. Franck
40 **Chemical testing of textiles**
Edited by Q. Fan
41 **Design and manufacture of textile composites**
Edited by A. C. Long
42 **Effect of mechanical and physical properties on fabric hand**
Edited by H. M. Behery
43 **New millennium fibers**
T. Hongu, M. Takigami and G. O. Phillips
44 **Textiles for protection**
Edited by R. A. Scott
45 **Textiles in sport**
Edited by R. Shishoo
46 **Wearable electronics and photonics**
Edited by X. M. Tao
47 **Biodegradable and sustainable fibres**
Edited by R. S. Blackburn
48 **Medical textiles and biomaterials for healthcare**
Edited by S. C. Anand, M. Miraftab, S. Rajendran and J. F. Kennedy
49 **Total colour management in textiles**
Edited by J. Xin
50 **Recycling in textiles**
Edited by Y. Wang
51 **Clothing biosensory engineering**
Y. Li and A. S. W. Wong
52 **Biomechanical engineering of textiles and clothing**
Edited by Y. Li and D. X-Q. Dai

53 **Digital printing of textiles**
Edited by H. Ujiie
54 **Intelligent textiles and clothing**
Edited by H. R. Mattila
55 **Innovation and technology of women's intimate apparel**
W. Yu, J. Fan, S. C. Harlock and S. P. Ng
56 **Thermal and moisture transport in fibrous materials**
Edited by N. Pan and P. Gibson
57 **Geosynthetics in civil engineering**
Edited by R. W. Sarsby
58 **Handbook of nonwovens**
Edited by S. Russell
59 **Cotton: Science and technology**
Edited by S. Gordon and Y-L. Hsieh
60 **Ecotextiles**
Edited by M. Miraftab and A. R. Horrocks
61 **Composite forming technologies**
Edited by A. C. Long
62 **Plasma technology for textiles**
Edited by R. Shishoo
63 **Smart textiles for medicine and healthcare**
Edited by L. Van Langenhove
64 **Sizing in clothing**
Edited by S. Ashdown
65 **Shape memory polymers and textiles**
J. Hu
66 **Environmental aspects of textile dyeing**
Edited by R. Christie
67 **Nanofibers and nanotechnology in textiles**
Edited by P. Brown and K. Stevens
68 **Physical properties of textile fibres Fourth edition**
W. E. Morton and J. W. S. Hearle
69 **Advances in apparel production**
Edited by C. Fairhurst
70 **Advances in fire retardant materials**
Edited by A. R. Horrocks and D. Price
71 **Polyesters and polyamides**
Edited by B. L. Deopura, R. Alagirusamy, M. Joshi and B. S. Gupta
72 **Advances in wool technology**
Edited by N. A. G. Johnson and I. Russell
73 **Military textiles**
Edited by E. Wilusz
74 **3D fibrous assemblies: Properties, applications and modelling of three-dimensional textile structures**
J. Hu
75 **Medical and healthcare textiles**
Edited by S. C. Anand, J. F. Kennedy, M. Miraftab and S. Rajendran
76 **Fabric testing**
Edited by J. Hu
77 **Biologically inspired textiles**
Edited by A. Abbott and M. Ellison
78 **Friction in textile materials**
Edited by B. S. Gupta
79 **Textile advances in the automotive industry**
Edited by R. Shishoo
80 **Structure and mechanics of textile fibre assemblies**
Edited by P. Schwartz

110 **Joining textiles: Principles and applications**
Edited by I. Jones and G. Stylios
111 **Soft computing in textile engineering**
Edited by A. Majumdar
112 **Textile design**
Edited by A. Briggs-Goode and K. Townsend
113 **Biotextiles as medical implants**
Edited by M. King and B. Gupta
114 **Textile thermal bioengineering**
Edited by Y. Li
115 **Woven textile structure**
B. K. Behera and P. K. Hari
116 **Handbook of textile and industrial dyeing. Volume 1: Principles, processes and types of dyes**
Edited by M. Clark
117 **Handbook of textile and industrial dyeing. Volume 2: Applications of dyes**
Edited by M. Clark
118 **Handbook of natural fibres. Volume 1: Types, properties and factors affecting breeding and cultivation**
Edited by R. Kozłowski
119 **Handbook of natural fibres. Volume 2: Processing and applications**
Edited by R. Kozłowski
120 **Functional textiles for improved performance, protection and health**
Edited by N. Pan and G. Sun
121 **Computer technology for textiles and apparel**
Edited by J. Hu
122 **Advances in military textiles and personal equipment**
Edited by E. Sparks
123 **Specialist yarn and fabric structures**
Edited by R. H. Gong
124 **Handbook of sustainable textile production**
M. I. Tobler-Rohr
125 **Woven textiles: Principles, developments and applications**
Edited by K. Gandhi
126 **Textiles and fashion: Materials design and technology**
Edited by R. Sinclair
127 **Industrial cutting of textile materials**
I. Vi umsone-Nemes
128 **Colour design: Theories and applications**
Edited by J. Best
129 **False twist textured yarns**
C. Atkinson
130 **Modelling, simulation and control of the dyeing process**
R. Shamey and X. Zhao
131 **Process control in textile manufacturing**
Edited by A. Majumdar, A. Das, R. Alagirusamy and V. K. Kothari
132 **Understanding and improving the durability of textiles**
Edited by P. A. Annis
133 **Smart textiles for protection**
Edited by R. A. Chapman
134 **Functional nanofibers and applications**
Edited by Q. Wei
135 **The global textile and clothing industry: Technological advances and future challenges**
Edited by R. Shishoo
136 **Simulation in textile technology: Theory and applications**
Edited by D. Veit
137 **Pattern cutting for clothing using CAD: How to use Lectra Modaris pattern cutting software**
M. Stott

138 **Advances in the dyeing and finishing of technical textiles**
M. L. Gulrajani
139 **Multidisciplinary know-how for smart textiles developers**
Edited by T. Kirstein
140 **Handbook of fire resistant textiles**
Edited by F. Selcen Kilinc
141 **Handbook of footwear design and manufacture**
Edited by A. Luximon
142 **Textile-led design for the active ageing population**
Edited by J. McCann and D. Bryson
143 **Optimizing decision making in the apparel supply chain using artificial intelligence (AI): From production to retail**
W. K. Wong, Z. X. Guo and S. Y. S. Leung
144 **Mechanisms of flat weaving technology**
V. Choogin, P. Bandara and E. Chepelyuk
145 **Innovative jacquard textile design using digital technologies**
F. Ng and J. Zhou
146 **Advances in shape memory polymers**
J. Hu
147 **Design of clothing manufacturing processes: A systematic approach to planning, scheduling and control**
J. Geršak
148 **Anthropometry, apparel sizing and design**
D. Gupta and N. Zakaria

Preface

Globalisation and the structural changes in the world's economy have had a considerable influence on the textile and clothing industries. During the past ten years, there have been indications of the emergence of a post-industrial production system that is able to achieve the goal of mass-customised, low-volume production. In this production process, each new product can be optimised or adapted for personal taste or individual needs. This calls for new approaches and solutions, as well as radical changes in the complete textile and clothing chain. These changes need to focus on four key elements:

1. creativity in design as a driver of user-centred innovation,
2. innovations in materials and processes,
3. flexibility in manufacture, and management in the supply chain, and
4. high quality of products and development of new services focused on customer needs.

Furthermore, today's rapid development of digital networks and communications technologies is having a revolutionary impact on product design and manufacturing processes. The conventional borders between product design, production and the user are beginning to merge. Digital and communications technologies enable the co-creation of products or/and services that can engage users from the outset. In addition to continuing to develop knowledge on how to design better products and services, we need also to design better clothing manufacturing processes to help the clothing industry to compete more effectively.

Design of clothing manufacturing processes plays an essential role in introducing new products, particularly in the ability to adapt quickly to dynamic changes in the global market. The following eight chapters provide a critical overview of key aspects of the design of more rapid, integrated and flexible clothing manufacturing processes Chapter 1 gives a general overview of clothing classification systems and terminologies for individual clothing types. Managing global production operations, with designers, fabric producers, clothing manufacturers, retailers and customers scattered across different locations, makes it essential to agree common classification systems for clothing. There is a similar need for standardisation in the area of sizing. Chapter 2 therefore provides an overview of the development and analysis of sizing systems of clothing and the manner in which information about agreed sizing systems is shared across countries and regions. The design of clothing manufacturing processes must also take into account how clothing collections are put together and launched. Chapter 3 reviews the key issues in developing a garment collection. These chapters provide the context for designing particular clothing manufacturing processes.

The following chapters discuss particular aspects in the design of clothing production operations. Chapter 4 discusses key terms and roles in clothing production planning and organisation. It reviews issues and documentation in design analysis and activity planning. The specific issues in the design of pattern making and cutting operations are discussed in Chapter 5. Chapter 6 deals with planning clothing manufacturing operations, including the selection of particular techniques and equipment as well as different process layouts. Production scheduling, monitoring and control are covered in Chapter 7. The last Chapter provides an overview of quality requirements for clothing textile materials, definitions and minimum quality standards.

The book is intended for a wide spectrum of readers, including students, researchers and academics, as well as professionals in the field of clothing design, engineering and other aspects of clothing production.

Jelka Geršak,
University of Maribor, Slovenia

1
Clothing classification systems

DOI: 10.1533/9780857097835.1

Abstract: This chapter gives a general overview of clothing classification systems. The first part includes a general classification of clothing and a harmonised customs-based classification system. The second part presents a functionality-based classification which covers the logical types of functional clothing. The chapter includes both classifications and significant terminologies for individual clothing types.

Key words: clothing, classification, functional clothing, protective clothing, medical clothing, sportswear, clothing terminology.

1.1 Introduction

Clothing appears to be basic to civilisation (Hollander, 1993). It is a term referring to a covering that is worn to cover the body or to keep warm. It is exclusively a human characteristic, and is a feature of nearly all human societies. The kind and type of clothing worn depends on functional considerations (such as the need for warmth or protection from the elements) and social considerations. The functionality required may differ greatly, depending on its end-uses. Functions include:

- everyday seasonal clothing,
- clothing for protection against extreme environmental conditions,
- sportswear,
- protective clothing for specialist functions (e.g. flame-resistant clothing for firefighters, military clothing),
- medical clothing and allied products.

Clothing may be divided into many types displaying different styles and features. There is no set standard for their classification. Different classifications give rise to different names for clothing. This chapter gives an overview of classification systems as well as commonly used terminologies for individual clothing types.

1.2 General clothing classification

Clothing and related products include all items of clothing and accessories worn by men, women and children of all ages, with the exception of hosiery (stockings, socks and tights) and overgarments such as galoshes (waterproof shoes worn over conventional shoes), umbrellas, etc. From the point of view of many clothing manufacturers, there are five basic areas within clothing production:

- men's outerwear,
- women's outerwear,
- children's clothing,
- underwear,
- knitted clothing.

Table 1.1 shows the types of clothing as they relate to areas of production.

Different countries have their own approaches. As an example, the Committee for the Preparation of Acts and Regulations at the Slovenian Ministry of the Economy divides textile and leather products into four groups (SCC, 2005):

- group A – yarns and threads,
- group B – fabrics,
- group C – clothing,
- group D – other textile and leather products.

Articles of clothing (Group C according to the above classification), are divided into seven sub-groups. These are:

- leather garments,
- outerwear, underwear,
- sports clothing,
- workwear,
- protective clothing,
- other clothing,
- clothing accessories.

The division of articles of clothing by subgroups is shown in Table 1.2 (SCC, 2005).

In addition to the above classification, there is also a general classification of clothing and sewn articles which includes groups of men's and boys' clothing, and women's and girls' clothing. These groups are further subdivided into:

- outerwear,
- uniforms,
- workwear,
- knitted outerwear,
- sports clothing,
- underwear,
- other clothing and clothing accessories, as shown in Table 1.3 (Anon., 1989).

Table 1.1 Areas of clothing production

Area		Clothing type
Men's outerwear		• Men's suits • Jackets • Trousers • Coats • Raincoats • Sports clothing • Men's uniforms • Workwear, etc.
Women's outerwear		• Women's blouses and dresses • Women's costumes • Women's jackets • Women's slacks • Women's coats • Women's raincoats • Women's sports clothing • Women's uniforms • Women's workwear, etc.
Children's clothing		• Boys' suits • Coats • Jackets • Trousers • Shirts • Girl's dresses • Coats • Jackets • Girl's skirts and trousers • Blouses • Children's blouses and dresses
Underwear	Men's underwear	Shirts, pyjamas, underpants, trunks, dressing gown, bathing wraps, etc.
	Women's underwear	Slips, corsets, bras, panties, bathing suits, pyjamas, nightgowns, housecoats, etc.
	Children's underwear	Undershirts, pyjamas, underpants, baby's underwear, bathing suits, bathing coats
	Bed linen	Quilt cases, sheets, pillow cases, etc.
	Napery	Table cloths, serviettes, etc.
Knitted fabrics/ knitwear	Knitted underwear	• T-shirts, undershirts • Men's underpants • Women's panties • Slips • Trunks, bathing suits, bathing coats, etc.
	Knitted outerwear	• Cardigans • Pullovers • Jackets • Trouser, etc.

Table 1.2 Article of clothing classification

Group	Sub-group/ name	Clothing type
C	**C_1**	Leather clothing • Leather coats and capes, compose, jackets, trousers
	C_2	Outerwear • Gowns, coats, capes, anoraks, windcheaters, jackets, waistcoats, pullovers, jumpers, waistcoats, jackets, dresses, costumes, skirts, trousers, divided skirts, jumpsuits, shorts, etc.
	C_3	Underwear • Shirts, blouses, T-shirts, polo-shirts and similar shirts, underpants and vests, bodies, slips, pyjamas, nightdress, bathing-wrap, etc. • Brassieres, bodices • Pantyhose, stockings
	C_4	Sports clothing • Sweatsuits, skiing suits, bathing suits and other sports clothing (with the exception of various protective devices, such as knee pads, various protectors, etc.)
	C_5	Workwear • Boiler suits, jackets, skirts, trousers, gowns, aprons etc. • Disposable clothing (in medicine, healthcare, laboratories, etc.)
	C_6	Protective clothing • Protective clothing (for firemen, foresters, in welding and similar processes, anti-radiation etc.), safety and bulletproof vests, etc. • Safety gloves
	C_7	Other clothing and clothing accessories
	$C_{7/1}$	• Clothing for infants (rompers, underwear, etc.)
	$C_{7/2}$	• Textile and leather gloves, mittens, dress gloves, sports gloves • Other hand coverings
	$C_{7/3}$	• Scarves, neckwear, shawls • Handkerchiefs, decorative handkerchiefs, etc. • Textile belts (together with watch-belts) • Suspenders
	$C_{7/4}$	• Bibs • Sleeve-reinforcement tapes, sleeve protectors used during writing • Garters, hosiery belts • Muffs, leggings • Neckties and bow ties • Hat hoods • Sweatbands, hair ribbons, hairnets, etc. • Collars (fur, embroidered, lace, etc.) • Zippers • Buttons and toggles, fabric coated • Protective devices (elbow protectors, knee pads, etc.) • Labels and tags, decorative pieces sewn on the clothing.

Table 1.3 General classification of articles of clothing

Clothing group/sewn articles	Clothing type
Men's and boys' outerwear	• Men's suits • Trousers • Coats
Women's and girls' outerwear	• Blouses • Dresses • Sets • Skirts • Coats
Uniforms	
Workwear, protective clothing, hospital clothing	
Knitted outerwear	• Vests • Pullovers • Skirts • Trousers and slacks • Dresses
Sports clothing	• T-shirts • Sweatsuits • Pullovers
Underwear (woven and knitted)	• Shirts • Undershirts • T-shirts • Pyjamas
Corsets, bras, hosiery belts	
Hosiery, pantyhose, gloves	
Bathing gown, bathing costume and trunks	
Shawls, scarves, kerchiefs, neckties	
Caps, hats, fur caps	
Bedding, house textiles, textiles for hospitality services	

1.3 Harmonised clothing classification systems

In addition to general classification systems for clothing, most developed and developing countries have now adopted harmonised classification systems to facilitate trade and customs tariffs. The USA has adopted a ten-digit code known as the 'HTS code'. This is based on a Harmonised System annotated for the purpose of statistical reporting (USITC, 2012). The UK has also adopted a ten-digit code known as the 'UK Tariff', or the Customs Handling of Import and Export Freight (CHIEF) system (HMRC, 2012). The European Economic Community (EEC) has adopted an eight-digit code known as 'TARIC', which is also based on the Harmonised System. The legal basis of TARIC is Council Regulation (EEC) No 2658/87 on the tariff and statistical nomenclature, and on the Common Customs Tariff (Anon., 1987), as amended. The purpose of this regulation is to establish a

Combined Nomenclature which meets the Customs Union Tariff and statistical requirements, and to create an Integrated Tariff of the European Communities (Commission Regulation (EU) No 1006/2011). India has also adopted an eight-digit code based on the Harmonised System. This is known as the 'Indian Trade Classification (ITC – HS)' (Kumar, 2010).

According to the Harmonised Tariff Schedule of the United States (USITC, 2012), and European TARIC (Fabio, 2010) Combined Nomenclature (Commission Regulation (EU) No 1006/2011), textiles and textile articles are covered under Section XI of the Harmonised System, in which nomenclatures are arranged in 99 chapters. These are organised into sections I through to XXII.

Section XI Textile and textile articles consists of 14 chapters:

Chapter 50	Silk
Chapter 51	Wool, fine or coarse animal hair; horsehair yarn and woven fabric
Chapter 52	Cotton
Chapter 53	Other vegetable textile fibres; paper yarn and woven fabrics of paper yarn
Chapter 54	Man-made filaments
Chapter 55	Man-made staple fibres
Chapter 56	Wadding, felt and non-wovens; special yarns, twine, cordage, ropes and cables and articles made thereof
Chapter 57	Carpets and other textile floor coverings
Chapter 58	Special woven fabrics, tufted textile fabrics, lace, tapestries, trimmings, embroidery
Chapter 59	Impregnated, coated, covered or laminated textile fabrics, textile articles of a kind suitable for industrial use
Chapter 60	Knitted or crocheted fabrics
Chapter 61	Articles of apparel and clothing accessories, knitted or crocheted
Chapter 62	Articles of apparel and clothing accessories, not knitted or crocheted
Chapters 63	Other manufactured textile articles; sets, worn clothing and worn textile articles, rags.

The classification and categories of clothing products under the Harmonised System according to Chapters 61, 62 and 63 are shown in Table 1.4. These sections are further subdivided into types of material: cotton, wool, polyester, silk, etc.

Chapter 61 covers made up knitted or crocheted articles, as well as babies' nappies. This chapter does not cover: (a) goods of heading 6212, (b) worn clothing or other worn articles of heading 6309, or (c) orthopaedic appliances, surgical belts, trusses or similar products (heading 9021). It includes

Table 1.4 Classification and categories of articles of clothing and clothing accessories in the Combined Nomenclature (Commission Regulation (EU) No 1006/2011)

Chapter	Heading/ subheading	Article description
Chapter 61	6101	Men's or boys' overcoats, car coats, capes, cloaks, anoraks (including ski-jackets), windbreakers and similar articles, other than those of heading 6103:
	6101 20	Of cotton:
	6101 20 10	Overcoats, car coats, capes, cloaks and similar articles …
	6101 20 90	Anoraks (including ski-jackets), windcheaters, wind-jackets and similar articles …
	6101 30	Of man-ma'de fibres:
Chapter 61	6102	Women's or girls' overcoats, car coats, capes, cloaks, anoraks (including ski-jackets), windbreakers and similar articles, other than those of heading 6104:
	6102 10	Of wool or fine animal hair:
	6102 10 10	Overcoats, car coats, capes, cloaks and similar articles …
	6102 20	Of cotton:
Chapter 61	6103	Men's or boys' suits, ensembles, jackets, blazers, trousers, bib and brace overalls, breeches and shorts (other than swimwear), knitted or crocheted:
	6103 10	Suits:
	6103 10 10	Of wool or fine animal hair …
	6103 20	Ensembles:
	6103 30	Jackets and blazers:
Chapter 61	6104	Women's or girls' suits, ensembles, jackets, blazers, dresses, skirts, divided skirts, trousers, bib and brace overalls, breeches and shorts (other than swimwear), knitted or crocheted:
	6105	Men's or boys' shirts, knitted or crocheted:
	6106	Women's or girls' blouses, shirts and shirt-blouses, knitted or crocheted:
Chapter 61	6107	Men's or boys' underpants, briefs, nightshirts, pyjamas, bathrobes, dressing gowns and similar articles, knitted or crocheted:
	6108	Women's or girls' slips, petticoats, briefs, panties, nightdresses, pyjamas, negligees, bathrobes, dressing gowns and similar articles, knitted or crocheted:
	6109	T-shirts, singlets and other vests, knitted or crocheted:

(*Continued*)

Table 1.4 Continued

Chapter	Heading/ subheading	Article description
	6110	Jerseys, pullovers, cardigans, waistcoats and similar articles, knitted or crocheted:
	6111	Babies' garments and clothing accessories, knitted or crocheted:
	6112	Tracksuits, ski-suits and swimwear, knitted or crocheted:
	6113	Garments, made up of knitted or crocheted fabrics of heading 5903, 5906 or 5907:
	6114	Other clothing
	6115	Pantyhose, tights, stockings, socks and other hosiery, including graduated compression hosiery (for example, stockings for varicose veins) and footwear without applied soles, knitted or crocheted:
	6116	Gloves, mittens and mitts, knitted or crocheted:
	6117	Other made-up clothing accessories, knitted or crocheted; knitted or crocheted parts of garments or of clothing accessories:
Chapter 62	6201	Men's or boys' overcoats, car coats, capes, cloaks, anoraks (including ski-jackets), windcheaters, wind-jackets and similar articles, other than those of heading 6203:
	6202	Women's or girls' overcoats, car coats, capes, cloaks, anoraks (including ski-jackets), windcheaters, wind-jackets and similar articles, other than those of heading 6204:
Chapter 62	6203	Men's or boys' suits, ensembles, jackets, blazers, trousers, bib and brace overalls, breeches and shorts (other than swimwear):
	6204	Women's or girls' suits, ensembles, jackets, blazers, dresses, skirts, divided skirts, trousers, bib and brace overalls, breeches and shorts (other than swimwear):
	6205	Men's or boys' shirts:
	6206	Women's or girls' blouses, shirts and shirt-blouses:
	6207	Men's or boys' singlet's and other undershirts, underpants, briefs, nightshirts, pyjamas, bathrobes, dressing gowns and similar articles:
	6208	Women's or girls' singlet's and other undershirts, slips, petticoats, briefs, panties, nightdresses, pyjamas, negligees, bathrobes, dressing gowns and similar articles:
	6209	Babies' garments and clothing accessories:
	6210	Clothing, made up of fabrics of heading 5602, 5603, 5903, 5906 or 5907

Table 1.4 Continued

Chapter	Heading/ subheading	Article description
	6211	Track suits, ski-suits and swimwear; other clothing:
	6212	Brassieres, girdles, corsets, braces, suspenders, garters and similar articles and parts thereof, whether or not knitted or crocheted:
	6213	Handkerchiefs:
	6214	Shawls, scarves, mufflers, mantillas, veils and the like:
	6215	Ties, bow ties and cravats:
	6216	Gloves, mittens and mitts:
	6217	Other made-up clothing accessories; parts of garments or of clothing accessories, other than those of heading 6212:
Chapter 63	6301	Other made-up textile articles. Blankets and travelling rugs:
	6302	Bed linen, table linen, toilet linen and kitchen linen:
	6303	Curtains (including drapes) and interior blinds; curtain or bed valances:
	6304	Other furnishing articles, excluding those of heading 9404:
	6305	Sacks and bags, of a kind used for the packing of goods:
	6306	Tarpaulins, awnings and sunblinds; tents; sails for boats, sailboards or landcraft; camping goods:
	6307	Other made-up articles, including dress patterns:
	6308	Sets consisting of woven fabric and yarn, whether or not with accessories, for making up into rugs, tapestries, embroidered tablecloths or serviettes, or similar textile articles, put up in packings for retail sale …

definitions of specific clothing and sets of clothing. For the purposes of headings 6103 and 6104 (Commission Regulation (EU) No 1006/2011) two examples relating to 'suits' and 'ensembles' are given as follows.

The term 'suit' means a set of garments consisting of two or three pieces, of which the outer surfaces are made in identical fabric. All the components of a suit must be of the same fabric construction, colour and composition. They must also be of the same style and of corresponding or compatible size. However, these components may have piping (a strip of fabric sewn into the seam) in a different fabric. The term 'suit' includes the following sets of garments, even where they do not fulfil all the above conditions:

- morning dress, comprising a plain jacket (cutaway) with rounded tails and striped trousers,
- evening dress (tailcoat), generally made of black fabric, the jacket of which is relatively short at the front, does not close, and has narrow skirts which are cut in at the hips and hang down behind,
- dinner jacket suits, in which the jacket is similar in style to an ordinary jacket but has shiny silk or imitation silk lapels.

The term 'ensemble' means a set of clothing (other than suits and articles of heading 6107, 6108 or 6109), which consists of several pieces made up in identical fabric, offered for retail sale, and comprising:

- one type of clothing designed to cover the upper part of the body, with the exception of pullovers, which may form a second type of upper clothing in the sole context of twin sets, and waistcoats, which may also form a second type of upper clothing,
- one or two different types of clothing, designed to cover the lower part of the body and consisting of trousers, bib and brace overalls, breeches, shorts (other than swimwear), skirt or divided skirt.

All the components of an ensemble must be of the same fabric construction, style, colour and composition. They must also be of corresponding or compatible size. The term 'ensemble' does not apply to track suits or ski-suits of heading 6112.

The clothing classifications presented above refer particularly to everyday seasonal clothing which is required to provide protection and comfort within a range of 'normal' wear and weather conditions. These include heat insulation, mechanical strength, abrasion resistance, ultraviolet protection, breathability, heat and vapour transport, and wind- and water-proof characteristics (Grishanov, 2010). Functional clothing, designed to meet performance requirements under extreme or specific conditions, is excluded from this classification.

1.4 Classification of functional clothing

Functional clothing is defined as that specifically designed and engineered to ensure predefined performance requirements and/or functionality for the user. This includes protection under harsh environmental conditions during work or sporting activities and protection against extreme hazards and environments. It may also include clothing for use in monitoring and evaluating hazards in conditions under which conventional everyday seasonal clothing would not be adequate (Geršak and Marčič, 2011). The functionalities required of clothing can be very different, depending on the end-use.

Only a few examples of more widely-used functional clothing are presented here, as the area is complex and broad. Functional clothing may be classified according to the main application areas, defined by Techtextil, which defines 12 main application areas for technical textiles (Byrne, 2000), divided into following groups:

- protective clothing (Protech),
- sports-functional clothing (Sporttech),
- medical-functional clothing (Medtech),
- clothing for special needs.

The performance of textile materials is frequently used in describing functional clothing. In the case of activity clothing, this user-requirement is usually specific and complex. Some key areas for the application of functional clothing will be presented with regard to the above classification.

1.4.1 Protective clothing

According to the European Standard EN 340, protective clothing can be defined as clothing including those protectors which cover or replace personal clothing and which are designed to provide protection against one or more hazards (EN 340, 2003). Particular clothing may be designed to provide protection against hazards encountered during specific types of work. Examples include garments providing protection against cuts, abrasion, ballistic and other types of severe impact, including stab-wounds and explosions, fire and extreme heat, hazardous dust and particles, nuclear, biological and chemical hazards, high voltages, static electricity and extreme cold. High-visibility wear also comes into this category.

Under the strict regulations placed upon employers by the introduction of legislation, such as the Personal Protective Equipment (PPE) at Work Regulation (European Union), it is necessary to ensure that protective clothing is adequate for meeting anticipated hazards and is used effectively. The clothing must be well designed and comfortable to wear. Protective clothing, considered as an integral part of PPE, is covered by the Personal Protective Equipment Directive (Directive 89/686/EEC) and is divided into three categories:

Category I – 'Simple'-designed Personal Protective Equipment. This covers exclusively PPE intended to protect the wearer against:

- mechanical actions with superficial effects,
- cleaning materials with mild and easily reversible effects,
- risks encountered during the handling of hot components not exposing the user to a temperature exceeding 50°C,

- dangerous impacts which do not affect vital areas of the body and cannot cause irreversible lesions.

Category II – 'Intermediate'-designed Personal Protective Equipment – PPE that is neither simple nor complex, for example, high-visibility clothing.

Category III – 'Complex'-designed Personal Protective Equipment – PPE intended to protect against life-threatening dangers, or dangers which may pose a serious and irreversible threat to the health of an individual, the immediate effects of which cannot be identified in sufficient time, and covers exclusively:

- respiratory protection devices providing full insulation from the atmosphere, including those for use in diving;
- PPE providing only limited protection against chemical attack or ionising radiation;
- emergency equipment for use within high-temperature environments, comparable to an air temperature of 100°C or more and which may or may not be characterised by the presence of infrared radiation, flames or the projection of large amounts of molten material;
- emergency equipment for use within low-temperature environments, comparable to an air temperature of –50°C or less;
- PPE to protect against falls from a great height;
- PPE to protect against electrical risks and dangerous voltages, or which is used as insulation during high-tension work.

Classification covering types of protective clothing according to the Personal Protective Equipment (Directive 89/686/EEC), is given in Table 1.5. The classification is based on the need for adequate standards of protection, and does not cover military clothing or clothing ensembles.

1.4.2 Sports-functional clothing

Sports-functional clothing differs from casual clothing in that it often has features which enhance functionality. Sports clothing requires a high-level of breathability and moisture/vapour transfer combined with heat insulation and/or wind-proofing, waterproofing, and UV protection. In many applications, functionality must be considered in conjunction with interactions between bodily activity, clothing, and the environment.

Sports clothing is a general term and it is necessary for garments to meet specific functional requirements, which will depend on the sport and its environment, as well as the construction, mechanical, physiological and/or aerodynamic characteristics and form of the clothing. The required functionality may thus differ greatly, and may be based on the application of

Table 1.5 Classification of protective clothing

The need of protection	Kind of protective clothing
Protection against mechanical impact	Special workwear, which must be sufficiently shock-absorbent to prevent injury resulting, in particular, from the crushing, etc., at last up an impact-energy level • Motorcyclists' protective clothing (EN 1621; EN 1621–1, 1997; EN 1621–2, 2003) • Protective clothing for horse riders (protective jackets, body and shoulder protectors) (EN 13158, 2009) • Protective clothing for professional motorcycle riders (jackets, trousers, one-piece or divided suits) (EN 13595–1, 2002)
Protection against physical injury (abrasion, perforation, cuts, bites)	Protective clothing again abrasion, protective clothing against perforation, cut resistant protective clothing. • Aprons, trousers and vest protecting against cuts and stabs by hand knives (EN ISO 13998, 2003) • Protective clothing for abrasive blasting operations using granular abrasives (ISO 14877, 2002) • Protective clothing for users of hand-held chainsaws – resistance to cutting by a chainsaw (EN 381–1, 1993)
Protection of drowning	• Lifejackets, lifesaving suit • Buoyancy aids clothing which will ensure an effective degree of buoyancy
Protection against heat and/or fire	• Protective clothing for protection against heat and flame (ISO 14116, 2008; EN ISO 11612, 2009) • Protective clothing for firefighters (EN 469, 2007) • Protective clothing for use in welding and allied processes (EN 470–1, 1995; ISO 15384, 2003; ISO 11611, 2007) • Protective clothing for workers exposed to heat (excluding firefighters' and welders' clothing) (EN 531, 1995) • Protective clothing against the thermal hazards of an electric arc (IEC 61482–2, 2009) • Protective clothing with electrostatic resistance – when the worker is exposed to environments where a spark could cause explosions or ignite fires, e.g. petrol stations, petrol tanker drivers, flour mills, clean rooms etc. (EN 1149, 1995). Protective clothing can be classified according to the type of fabric used: clothing with surface conducting fabrics (EN 1149–1, 2006), and clothing with corona fabrics (EN 1149–5, 2008) • Protective clothing for automobile racing drivers (ISO 14460, 1999)

(*Continued*)

Table 1.5 Continued

The need of protection	Kind of protective clothing
Protection against cold	• Protective clothing against cold (EN 342, 2004)
Protection against rain	Protective clothing for protection against rain (EN 343, 2003+A1, 2007; EN 14360, 2004)
Protection against electric shock	• Electrical insulating protective clothing for low-voltage installation (EN 50286, 1999) • Conductive clothing for live working at a nominal voltage (EN 60895, 1997) • Protective shielding clothing for live working (Herzberg *et al.*, 2001)
Protection against radiation	• Protective clothing against radioactive contamination (EN 1073–1, 1998; ISO 8194, 1987) • Protective clothing against radioactive particulate matter
Protection against dangerous substances and infective agents	Clothing for protection against penetration or skin contact with hazardous chemicals, toxic gases, body fluids: • Protective clothing for protection against chemicals (ISO 16602, 2007) • Clothing for protection against liquid chemicals (ISO 13994, 2005) • Chemical protective clothing for use against solid particulates (ISO 13982–1, 2004) • Clothing for protection against contact with blood and body fluids (ISO 16603, 2004) • Clothing for protection against infectious agents (ISO 22609, 2004)
Protection against invisibility	• High-visibility warning clothing for professional use (EN 471, 2003) • Visibility clothing for non-professional use (EN 1150, 1999)

compression or the principles of aerodynamics to reduce wind or air-drag during high speed sports. Compression clothing (e.g. tights, clothing, and stockings) includes elastic, body-moulded suits with an engineering compression gradient and which may be worn as upper or lower body pieces (Perrey, 2010). The function of aerodynamic clothing (i.e. garments for athletic or cycling wear) is to trap a thin layer of air next to the body (Kyle and Caiozzo, 1986; Brownlie *et al.*, 2004). Both principles may be used in combination or individually, according to the requirements. Further classification of sports-functional clothing is given in Table 1.6.

Table 1.6 Classification of sports-functional clothing

Sport	Kind of clothing
Golf	• Golf stylish clothing (allow also a casual or a formal look of clothing)
Tennis	• Short tennis skirts, t-shirts • Tennis dresses made out of a variety of high performance fabrics • Men shorts, t-shirts
Soccer	• Soccer uniform
Basketball	• Basketball wear
Baseball	• Baseball uniform (sliding shorts and jerseys)
Football	• Football shirts, football shorts • Protective clothing – shin guards (EN 13061, 2009)
Contact sports (like American football and ice hockey)	• Adequate uniform as protective clothing with chest guard
Swimming	• Swimsuit, bathing suit, swimming costume • Professionals skintight costumes • Bodysuits, called as dive skins
Diving	• Diving suit • Wetsuits
Running	• Women's running clothing (lightweight performance in an athletic design) • Men's running clothing (lightweight performance in an athletic design) • Skintight garment
Skiing	• Ski suit, snowsuit • Jumpsuit (two-piece, in the form of a ski jacket and matching trousers) • Racing suit • Cross-country gear • Ski jacket
Ice skating	• Skating dress • Speed skating dress
Cycling	• Cyclist wear
Motocross/ motorcycle riding	• Protective clothing for professional motorcycle riders (jackets, trousers, one-piece or divided suits)
Aeronautics	• One-piece flying suit
Fencing	• Fencing clothes, jacket, knickers
Karate	• Special karate clothing
Fitness clothing	• Men's t-shirts, tank tops, shorts, pants • Ladies sports bras, workout pants or shorts
Mountaineering/ alpine climbing	• Mountaineering clothing • Climbing clothing, climbing breeches, snowshirt • Expeditionary clothing • Wanderer clothing • Running wear

Table 1.7 Classification of medical-functional clothing

Areas of application	Kind of clothing
Healthcare/hygiene	• Healthcare uniform • Clothing for nursing staff, nurse's uniform • Clothing for patients, scrubs, patient wear • Medical coats, tabards • Medical protective clothing (in isolation wards and intensive care units) • Protective gown for dentist • Protective gown for veterinary
Surgery	• Surgical clothing • Surgeon's gowns, caps • Surgical cover cloths • Surgical hosiery • Surgical hosiery with graduated compression characteristics
Therapeutic clothing	• Pressure clothing • Tubular elasticised net garment • Far infrared therapeutic clothing • Infrared shapewear • Anti-microbial underwear • Anti-irritant's underwear (Patrizi *et al.*, 2011)
Intelligent functional clothing	• Cardiopulmonary resuscitation vest (Tsuji *et al.*, 1998) • EKG Vests for heart patients • Intelligent biomedical clothing • Intelligent clothing's physiological monitoring • Intelligent clothing in prehospital emergency care • Intelligent functional clothing for personal health records and medical information management

1.4.3 Medical-functional clothing

This category refers to functional clothing for healthcare. Characteristics typically include absorbency (wound-dressing), air permeability (surgeons' gowns, staff uniforms) and durability (pressure clothing). These types of functional clothing may be categorised into four separate and specialised areas of application, as follows:

- healthcare/hygiene clothing,
- surgical clothing,
- therapeutic clothing,
- intelligent functional clothing.

Healthcare/hygiene and surgical clothing are important sectors in the fields of medicine and surgery. They may be used in operating theatres and on hospital wards for the care, hygiene, and safety of staff and patients (Rigby and Anand, 2000; Podpovitny *et al.*, 2011). Therapeutic clothing includes pressure clothing and clothing designed specifically to aid in reducing the risk of infection. Intelligent functional clothing is a relatively new and specific area in medical-functional clothing. Table 1.7 illustrates the range of medical clothing described according to functional requirements or in providing protection against potential hazards to health.

1.4.4 Clothing for special needs

This category of clothing is concerned with improving the quality of life for people with special needs or disabilities. This includes wheelchair users, stroke victims, arthritis sufferers, and those with restricted movement. Special needs clothing for disabled people are garments made to measure for individual comfort. This includes clothing with modifications for paraplegics, the elderly and handicapped, hypo-allergenic garments, clothing for Alzheimer's sufferers, arthritis patients, incontinence sufferers, jumpsuits, sensory-perceptive children's clothing and clothing for those with other disabilities. The needs of each group are distinct. It is therefore necessary for the clothing to be engineered to specific requirements (Gupta, 2011). Design considerations include changes in body shape, limitation of mobility, ergonomic and physiological requirements and psychological and social needs.

1.5 Conclusions

Although there have recently been major developments in new materials and clothing products (e.g. wearable electronics), their classifications have not yet been systematically defined. It is necessary to establish a coherent and universally acceptable description and classification for such clothing. The classification systems presented here are for the purposes of general knowledge and the understanding of clothing requirements. Classification also contributes to the development of terminology in the field of clothing engineering. There are also important linguistic and cultural perceptions as to what constitutes clothing, across a range from everyday seasonal clothing to functional clothing.

1.6 References

Abreu, M. J., Silva, M. E., Schacher, L. and Adolphe, D. (2003), 'Designing surgical clothing and drapes according to the new technical standards', *International Journal of Clothing Science and Technology*, **15** (1), 69–74.

Anon. (1987), 'Council Regulation (EEC) No 2658/87 of 23 July 1987 on the tariff and statistical nomenclature and on the Common Customs Tariff'. *Official Journal* L 256.

Anon. (1989), *Textile lexicon* (in Slovenian), Ljubljana, University of Edvarda Kardelj in Ljubljana, Faculty of Science and Technology, Textile technology.

Brownlie, L. W., Kyle, C. R., Harber, E., MacDonald, R. and Shorten, M. R. (2004) 'Reducing the aerodynamic drag of sports apparel: Development of the Nike Swift sprint running and SwiftSkin speed skating suits', *The Engineering of Sport* **5**, **1**, 90–96 (edited by M. Hubbard, R.D. Mehta, J.M. Pallis) ISEA, Sheffield.

Byrne, C. (2000), *Technical textiles market – an overview*, Handbook of Technical Textiles, Cambridge, Woodhead Publishing Limited, 1–23.

CEN/TC 205/WG 14, prEN 13795: (2001), Surgical drapes, gowns and clean air suits, used as medical devices, for patients, clinical staff and equipment Part 1: General requirements for manufacturers, processors and products.

Commission Regulation (EU) No 1006/2011 of 27 September 2011 amending Annex I to Council Regulation (EEC) No 2658/87 on the tariff and statistical nomenclature and on the Common Customs Tariff, *Official Journal*, L 282, **54**, 28/10/2011, 343–410.

Council Directive 89/686/EEC of 21 December 1989 on the approximation of the laws of the Member States relating to personal protective equipment, *Official Journal*, L 399, 30/12/1989, 1838.

Denton, M. J. and Daniels, P. N. (2002), *Textile terms and definitions*, 11th Edition, Manchester, Textile Institute.

EN 340:2003 Protective clothing: General requirements, December 2003.

EN 342:2004 Protective clothing against cold.

EN 343:2003+A1:2007 Protective clothing Protection against rain.

EN 381–1:1993 Protective clothing for users of hand-held chainsaws Part 1: Test rig for testing resistance to cutting by a chainsaw.

EN 469:2007 Protective clothing for firefighters – Performance requirements for protective clothing for firefighting.

EN 470–1:1995 Protective clothing for use in welding and allied processes Part 1: General requirements.

EN 471:2003 High-visibility warning clothing for professional use Test methods and requirements.

EN 531:1995 Protective clothing for workers exposed to heat.

EN 1073–1:1998 Protective clothing against radioactive contamination Part 1: Requirements and test methods for ventilated protective clothing against particulate radioactivate contamination.

EN 1149:1996 Protective clothing: Electrostatic properties.

EN 1149–1:2006 Protective clothing Electrostatic properties Part 1: Test method for measurement of surface resistivity.

EN 1149–5: 2008 Protective clothing Electrostatic properties Part 5: Material performance and design requirements.

EN 1150:1999 Protective clothing Visibility clothing for non-professional use Test methods and requirements.

EN 1621 Motorcyclists' Protective Clothing against mechanical impact.

EN 1621–1:1997 Part 1 – Requirements and test methods for impact protectors.

EN 1621–2:2003 Part 2 Requirements and test methods for motorcyclists back protectors.

EN ISO 11612: 2009 Protective clothing Clothing to protect against heat and flame.
EN 13061:2009 Protective clothing. Shin guards for association football players. Requirements and test methods.
EN 13158:2009 Protective clothing Protective jackets, body and shoulder protectors for equestrian use: For horse riders and those working with horses, and for horse drivers, Requirements and test methods.
EN 13595–1:2002 Protective clothing for professional motorcycle riders. Jackets, trousers and one piece or divided suits.
EN 14360:2004 Protective clothing against rain Test method for ready made garments – Impact from above with high energy droplets.
EN 50286:1999 Electrical insulating protective clothing for low-voltage installations.
EN 60895:2003 Live working. Conductive clothing for use at a nominal voltage up to 800 kV a.c. and ± 600 kV d.c.
Fabio, M. (2010), *Customs Law of the European Union*, Kluwer Law International BW, Netherlands.
Geršak, J. and Marčič, M. (2011), *The peculiarities of a complex design concept for functional protective clothing*, CBMTS Industry VII: The World Congress on the CBRN Threat and Terrorism, Cavtat.
Grishanov, S. (2010), *Fundamental modelling of textile fibrous structures, Modelling and predicting textile behaviour,* Edited by Chen, X., Cambridge, Woodhead Publishing Limited, 41–111.
Gupta, D. (2011), 'Functional clothing: Definition and classification', *Indian Journal of Fiber & Textile Research*, **35**, 321–326.
Herzberg, C., Rödel, H. and Engelmann, E. (2001), 'New shielding protective equipment for live working', *International Journal of Clothing Science and Technology*, **13**(3/4), 301–308.
HMRC (2012), *Integrated Tariff of the United Kingdom*, Volume 2 Schedule of duty and trade statistical descriptions, codes and rates, 2012 Edition, London, HM Revenue & Customs.
Hollander, A. L. (1993), *Seeing through clothes*, Berkeley, University of California Press.
IEC 61482–2: 2009 Protective clothing against the thermal hazards of an electric arc Part 2: Requirements.
ISO 8194:1987 Radiation protection Clothing for protection against radioactive contamination: Design, selection, testing and use.
ISO 11611:2007 Protective clothing for use in welding and allied processes.
ISO 13982–1:2004 Protective clothing for use against solid particulates Part 1: Performance requirements for chemical protective clothing providing protection to the full body against airborne solid particulates.
ISO 13994:2005 Clothing for protection against liquid chemicals – Determination of the resistance of protective clothing materials to penetration by liquids under pressure.
ISO 13998:2003 Protective clothing – Aprons, trousers and vests protecting against cuts and stabs by hand knives.
ISO 14116:2008 Protective clothing – Protection against heat and flame – Limited flame spread materials, material assemblies and clothing.
ISO 14460:1999 Protective clothing for automobile racing drivers – Protection against heat and flame – Performance requirements and test methods.

ISO 14877:2002 Protective clothing for abrasive blasting operations using granular abrasives.
ISO 15384:2003 Protective clothing used for wildland fire fighting – Laboratory test methods and performance requirements for wildland firefighting clothing.
ISO 16602:2007 Protective clothing for protection against chemicals – Classification, labelling and performance requirements.
ISO 16603:2004 Clothing for protection against contact with blood and body fluids – Determination of the resistance of protective clothing materials to penetration by blood and body fluids.
ISO 22609:2004 Clothing for protection against infectious agents – Medical face masks – Test method for resistance against penetration by synthetic blood.
Kumar, M. K. (2010), *Harmonized system of apparel classification and categories*, Textile Review, March 2010.
Kyle, C. R. and Caiozzo, V. J. (1986), 'The effect of athletic clothing aerodynamics upon running speed', *Medicine and Science in Sports and Exercise*, **18**(5), 509–515.
Marzano, S. (2000), The quest for power, comfort and freedom. In Eves, D. *et al.* eds, *New nomads: An exploration of wearable electronics by Philips*, 010 Publishers, Rotterdam, 4–9.
Patrizi, A., Giacomini, F., Gurioli, C. and Neri, I. (2011), 'Clinical effectiveness of a special silk textile in the treatment of recurrent pediatric inflammatory vulvitis: An open label pilot study', *Giornale Italiano di Dermatologia e Venereologia*, **146**(5), 317–320.
Perrey, S. (2010), 'Comression garment: Evidence for their physiological effects', *The Engineering of Sport*, **7**(2), 319–328.
Podpovitny, M., Schacher, L., Geršak, J. and Adolphe, D. C. (2011), 'Development of a new protective gown for dentists', *Tekstil*, **60** (10), 493–497.
Rigby, A. J. and Anand, S. C. (2000), *Medical textiles*, Handbook of Technical Textiles, Cambridge, Woodhead Publishing Limited, 407–424.
SCC (2005), *Regulations on designating textile and leather products* (in Slovenian), Ljubljana, Slovenian Chamber of Commerce.
Tsuji, T., Miyawaki, F., Fujisato, T., Moritan, T. and Fujimoto, T. (1998), *Development of a cardiopulmonary resuscitation vest equipped with a defibrillator*, Proceedings of the 20th Annual International Conference of the IEEE, **1**, 426–427.
USITC (2012), *Harmonized Tariff Schedule of the United States*, 24th edn, Washington, the United States International Trade Commission.

2
Clothing sizing systems

DOI: 10.1533/9780857097835.21

Abstract: This chapter provides an overview of the development and analysis of sizing systems for clothing, and the manner in which information about the designated systems is shared. The first part includes a short chronological survey of global studies and investigations in the field of anthropological measurements and the development of clothing sizing and designation systems. It continues with discussion of different sizing systems and designations. The chapter includes the European and international sizing systems which are based on body dimensions, the metric system, and data from new anthropometric studies of the population performed in the late 1990s.

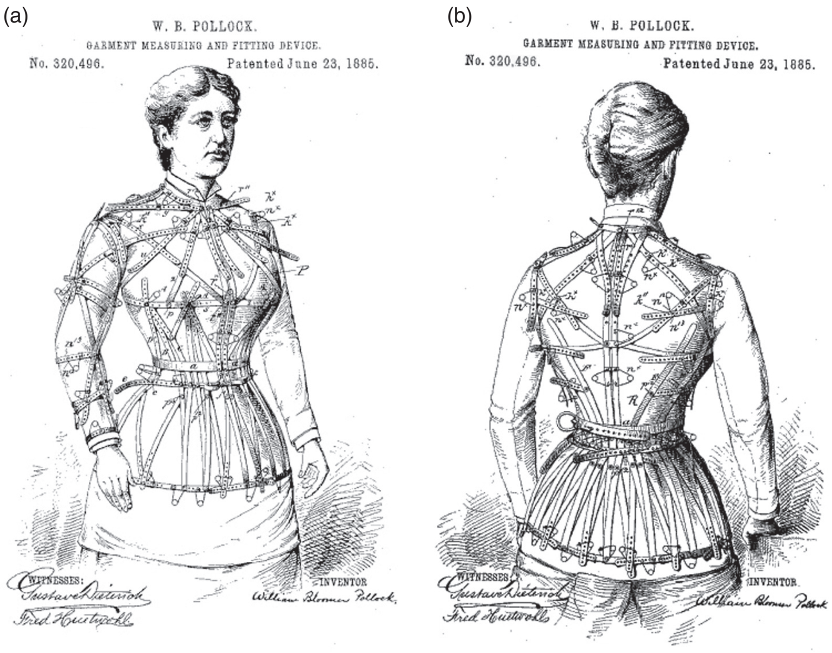
Key words: clothing, anthropometric measurements, sizing systems, designating.

2.1 Introduction

Until the first decades of the twentieth century, garments were usually made-to-measure, that is, made using the individual body measurements of each customer. However, tailors were constantly seeking to construct a proportional scale of body measurements which would allow them to construct ready-made clothes to fit different customers. Practical experience led to the development of several methods for determining clothing sizes. These were mostly adapted to a particular customer or to a relatively small group.

All systems of clothing sizes are based on anthropometric measurements of body height and figure type. The Belgian mathematician A. Quetelet (Porter *et al.*, 2003; Spatz, 2011; Anon., 2012a), carried out the first anthropometric measurements during the first half of the nineteenth century, with the aim of developing a system of standardised clothing sizes based on variation in body measurements. In 1844 he published his results after measuring various population groups and was able to derive a theoretical frequency distribution which closely predicted the observed variation in height, weight, and chest circumference of various groups in the population.

The need to design standardised systems for clothing sizes was a result of the mass production of clothing at the end of the nineteenth and the beginning of the twentieth centuries (Workman, 1991). Comprehensive anthropometric



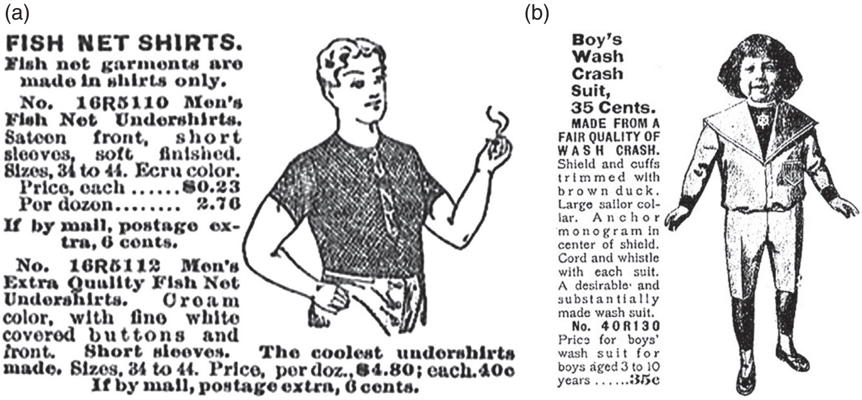
2.1 U.S. Patent applications for taking body measurements, no. 320,496, W. B. Pollock (Pollock, 1885): (a) front view of body-and-sleeve form of fitting device (b) a rear view of same.

measurements of the population were necessary for the design of such systems. Anthropometric measurements were performed in Germany as early as 1875 on army recruits. W.B. Pollock applied for the first patent in the area of clothing sizing in 1885 (Pollock, 1885) for a system of body measurement and the measuring of clothing sizes (Fig. 2.1). The results obtained indicate that the inhabitants of many developed countries have, on average, been growing taller. A considerable increase in the height of men has been recorded during the past 130 years – the average German is, for example, 16 cm taller than was the case a hundred years ago – an increase of more than 1 cm per decade (Anon., 2008a).

2.2 Clothing size and designation systems: a chronological review

This section provides a short chronological survey of global studies in the field of anthropological measurements and of the development of clothing sizing and designation systems:

1884 The first measurements for the purpose of standardising clothing sizes were the result of collecting women's body measurements at



2.2 An example of garment size designations in the *Sears* catalogue from 1902: (a) fish net shirt and (b) boy's wash crash suit.

high schools. This began at the Vassar College in New York in 1884, at Stanford University in California in 1890, and at the Schmith College in Massachusetts in 1903 (Ashdown, 1998).

1901 The American federal administration established the National Bureau of Standards (NBS),[1] to set standards for measurements in science and industry (CS 215–58, 1958).

1902 The retail catalogue *The 1902 Sears, Roebuck Catalogue* advertised garments with sizes marked by size and age, Fig. 2.2 (Anon., 1993, 2008b; Swearingen, 1999).

1921 The first report on American anthropological measurements was published, based on the measurements of around 100 000 males, at the time of the demobilisation following World War I (Fan *et al.*, 2004).

1921 The Office of Public Health in the State of Illinois published anthropometric tables of body measurements for children aged between 6 and 72 months (SDPH, 1921).

1937–38 Anthropometric measurements were organised in various climatic areas of Texas and in 13 other American states. These involved 3000 boys and 3535 girls between the ages of 7 and 14. They established size and garment construction standards (Whitacre and Grimes, 1959). The investigations were initiated by the National Bureau of Home Economics and the US Department of Agriculture, and included 36 measurements for each person tested. The study was performed in 1941 and provided basic data on the physical development of children.

[1] **NBS** [Engl. *N(ational) B(ureau) of S(tandards)*] – Bureau founded by Act of Congress on March 3rd 1901. It consisted of the Institute for Basic Standards, the Institute for Material Science, the Institute for Applied Technology, the Center for Computing and Technology and the Information Office (CS 215–58, 1958).

1937–39 Comprehensive anthropological measurements of 147 088 children, aged between 4 and 17 were organised for the purpose of predicting garment sizes and dimensions for desks and other school furniture (O'Brien, 1939, 1941). The results were published in the USDA Miscellaneous Publication No. 366 under the title *Body Measurements of American Boys and Girls for Garment and Pattern Construction* (CS151–50, 1945).

1939–40 The first comprehensive scientific investigation organised by the National Office of Internal Economy, US Department of Agriculture involved around 150 000 American women. The results were published in 1941 in the USDA Miscellaneous Publication No. 454 entitled *Women's Measurement for Garment and Pattern Construction* (NIST, 2011a, 2011b).

1945 Recommended Commercial[2] Standards were presented to distributors and users at the request of The Mail Order Association of America (MOAA) on 10 September 1945 and designated CS 151–50. These included anthropometric measurements for infants, young children and for boys and girls garment sizes. The standard for children's underwear was accepted 3 years later, in October 1948 (CS151–50, 1948).

1947 A non-governmental organisation for standardisation ISO[3] was established with the general secretariat in Geneva, Switzerland.

1953 Hungary developed a set of tables based on professional measurements and calculations, and issued the garment size standard MOSZ 6100–53 A. The standard covered 40–50% of the population (Dán and Déri, 1998).

1953–54 Hungary organised a programme of comprehensive anthropometric measurement, involving 40 752 people, and developed tables with new measurements. These tables have never been accepted in practice (Dán and Déri, 1998).

1954 The Danish Association for Standardisation issued their national standard DS 923 with sizes for woven garments (Fan *et al.*, 2004).

---

[2] **Commercial Standards (CS)** – commercial standards, developed by the industry, with the administrative and technical support of the Standards department at the National Bureau of Standards (NBS, (now NIST). Each commercial standard was afterwards subjected to further revisions and substitutions (NIST, 2011b).

[3] **ISO** [Engl. *I(nternational) S(tandardising) O(rganization*)] – The International Organisation for Standardisation is a worldwide federation of national standards bodies (ISO member bodies), including 157 states (one member per state) with the Secretary General coordinating the system in Geneva. The work of preparing International Standards is normally carried out through ISO technical committees. In Greek the word *isos* means *equal* and is the root of the prefix iso-, which is a foundation concept for international standardisation ISO, that is, isometry (equal measures), isonomy (equality in political rights), etc.

1955–59 The Polish Academy of Science, together with the Central Laboratory for the Clothing Industry, organised anthropometric measurements as a basis for establishing a national system of garment sizing.

1957 A garment-sizing system was developed in Great Britain. The Joint Clothing Council organised anthropometric measurements of 4349 women between the ages of 18 and 70. The Council developed a sizing system for women's garments and garment construction, based on data analysis of these measurements. Three types of women's figures were defined by height (short, medium and tall), as well as three types based on fullness of figure (slim, normal and full) (Chun-Yoon and Jasper, 1993).

1957–58 The Hohenstein Research Institute (Germany) conducted investigations into body measurements based on a representative number of measurements from women and girls (Schierbaum, 1993).

1958–59 Hungary conducted so-called control measurements of a significant number of the population (5000 men, 5000 women and 13 000 boys and girls), which were used to develop tables including 59 men's sizes, 41 women's sizes, 26 girls' and 32 boys' sizes. These tables have never been accepted in practice (Dán and Déri, 1998).

1957–65 The former Soviet Union carried out comprehensive measurements of major population groups, including men, women and children from various parts of the country.

1958 The American NBS issued a commercial standard CS 215–58 *Body Measurement for the Sizing of Women's Patterns and Apparel* (CS 215–58, 1958), based on anthropometric measurements carried out to determine women's garment sizes. The data used in the analysis were obtained in the period 1939–40 (NIST, 2011a) and the standard was developed at the request of MOAA.

1960–61 The German Research Institute in Hohenstein conducted anthropometric measuring of the female population for the German clothing industry with the aim of producing garments sized to fit the general population (Schierbaum, 1993).

1961 The National Committee for Standards established the European Committee for Standardisation CEN[4] for EU and EFTA[5] countries.

---

[4] **CEN** [Fr. *C(omité) E(uropéen)* de *N(ormalisation)*] – Established in 1961 at the National Body for Standards, within the European Economic Community and EFTA states. CEN is a major provider of European Standards and technical specifications. It is the only recognised European organisation in accordance with Directive 98/34/EC for the planning, drafting and adoption of European Standards in all areas of economic activity, with the exception of electro-technology (CENELEC) and telecommunications (ETSI).

[5] **EFTA** [Engl. *E(uropean) F(ree) T(rade) A(ssociation)*] – established by a Convention signed in Stockholm on 4 January 1960 (so called EFTA convention).

1962–63 The Yugoslav Committee for Standardisation organised systematic anthropometric measurements in Vojvodina (a province in Serbia), involving 5000 people of both sexes, aged between 2 and 55, who were divided into two groups. The first group consisted of people aged from 2 to 19 and the second consisted of those between 20 and 55 (Knez, 1994; Ujević *et al.*, 2006).

1962–63 Hungary again conducted anthropometric measurements based on international experience which, on this occasion, were much better prepared. The project involved 0.5% of the population, or 51 000 people between the ages of 16 and 60, as well as 2000 children from 6 months to 5 years. (Dán and Déri, 1998).

1963 The Yugoslav Department of Standardisation issued a study with the aim of meeting the needs of the clothing industry. It consisted of experimental anthropometric measurements of the inhabitants of Vojvodina (Balaban *et al.*, 1963).

1963 The Research Institute of Hohenstein issued tables of garment sizes for women's and girls' outerwear at the request of professional associations in Germany. The tables were based on anthropometric measurements carried out in 1957 and 1958, as well as on those from 1960 to 1961 (Schierbaum, 1982, 1993).

1963 The Netherlands Institute for standardisation (NNI) presented a standard for a garment-sizing system for men.

1965–66 Anthropometric measurements were undertaken on 7283 males in France, aged between 22 and 64 (Fan *et al.*, 2004).

1966 Bekleidungstechnisches Institut Mönchengladbach (Germany) issued tables of measurements for men's and boys' outerwear, based on more than 80 000 measurements of around 10 000 people (Schierbaum, 1982). The tables included 88 commercial sizes, among them 60 for men, 7 for boys and 21 for adolescents. Due to the growing importance of the European market, the tables included European sizes. German sizes were designated separately in accordance with the recommendations of the Association des Industris de l'Habillement (European Association of Clothing Industry). The European sizes consisted of three European identifying dimensions: body height, chest girth and waist girth. The German measurements consisted of half the chest girth and half the difference between the waist and chest girths and the average body height.

1966–67 The Japanese standard JIS offered a review of garment sizes based on the measurements of approximately 35 000 people.

[5] It was founded on the premise of free trade as a means of achieving growth and prosperity amongst its Member States as well as promoting closer economic cooperation between the Western European countries.

1968 An adaptation of the standard CS 215–58 was undertaken in May 1968 at the request of MOAA, for the purpose of obtaining a better match for the body measurements of the female population at the time (NIST, 2011c).

1969 Supplemented anthropometric measurements were carried out in France on 8037 women aged between 18 and 65, and on around 14 000 boys and girls aged between 4 and 21 (Fan *et al*., 2004).

1969 The first anthropological measurements were organised in Australia and involved 11 455 females.

1970 The American NBS issued a modernised commercial standard CS 215–58, dating from 1968, in a new edition, as a *Voluntary Product*[6] *Standard PS 42–70*, intended for commercial purposes (PS 42–70, 1970; NIST, 2011c).

1970 Germany again organised measurements of the female population, as field reports indicated that garment-sizing tables for women's and girls' outerwear had become outdated as body measurements and proportions had changed with time. Experts concluded that the female population should be measured every 10 years if the clothing industry was to produce garments based on realistic body measurements, able to meet the requirements of fitting well and presenting an attractive appearance (Anon., 1970; Schierbaum, 1982). This investigation was carried out by three institutions, the Hohenstein Research Institute (Forschungsinstitut Hohenstein), the Institute for Clothing Physiology (Bekleidungsphysiologischen Institut e.V.) Hohenstein, and a market research company from Hamburg (Gesellschaft für Marktforschung mbH). The measurements of 10 000 women and girls were taken and presented in tables for the construction of women's and girls' outerwear (Anon., 1970).

1972 The Swedish National Institute organised around 40 000 anthropometric measurements from approximately 1000 people. The sample was small and highly homogeneous.

1972 Tables of women's and girls' body measurements for outerwear were compiled for the second time in Germany in November 1972. For the first time, this included garment construction tables which incorporated around 6000 construction measurements (for 10 different height groups and 15 different size scales). This represented an important step forward in systematising garment construction (Schierbaum, 1982).

[6] **Voluntary Product Standards (VPS)** – non-obligatory standards for products developed by the Department of Commerce in May 1970. Voluntary Product Standards are completely free of any obligation (PS 42–70, 1970; NIST, 2011b).

1973 The former Soviet Union issued tables of garment sizes PC3137 and PC3138.

1974 The English standard was published for women's outerwear garment sizes, under the designation BS 3666 (BS 3666, 1974; Boughey, 1978).

1974 China began preparations for issuing garment-sizing standards, known as GB 1335–81. The standard was implemented in 1981 (Fan *et al.*, 2004).

1975 The International Organisation for Standardisation (ISO) developed a new system for size designation, with key dimensions and pictograms[7] of figure types, that is, pictorial symbols used to indicate the position on the body of the relevant dimensions.

1977 The Swedish Institute for Textile Research (TEFO) and the Association of Textile Industry (KIF) issued a sizing system for women's garments.

1977 Great Britain issued a standard for the size designation of clothing BS 5511 (BS 5511, 1977), which included definitions and measuring procedures.

1977–82 The ISO Technical Committee (ISO/TC)[8] 133, a part of the International Organisation for Standardisation, issued a series of standards in the field of garment designation size: ISO 3635, 1981, ISO 3636, 1977, ISO 3637, 1977, ISO 3638, 1977, ISO 4415, 1981, ISO 4416, 1981, ISO 4417, 1977, ISO 4418, 1978, ISO 5971, 1981, ISO 7070, 1982. The standard ISO 3635, dealing with the definitions and body measurement procedure, underwent two corrigenda.[9] The third edition was issued in 1981 (the second, which was corrected, was issued in 1979).

1978–81 Japan undertook comprehensive investigations involving some 50 000 people of both sexes and all age groups (Fan, 2004).

1979 The Yugoslav Department of Standardisation issued a series of ten standards dealing with the designation of garment sizes (JUS F.G0.001, 1979, JUS F.G0.002, 1979, JUS F.G0.003, 1979, JUS F.G0.004, 1979, JUS F.G0.005, 1979, JUS F.G0.006, 1979, JUS F.G0.007, 1979, JUS F.G0.008, 1979, JUS F.G0.009, 1979, JUS F.G0.010, 1979).

---

[7] **Pictogram** [Lat. *pictus* drawn + *gram* from Gr. *gramma, grammatos* letter; in compounds: presentation, written or drawn] – pictorial presentation, a symbol with an internationally accepted meaning; drawing or hieroglyph which represents an object or notion (Anon., 2002).

[8] **TC** [Engl. *T(echnical) C(ommittee)*] ISO/TC 133, a sizing system and designations for clothes; ISO Technical Committee preparing the international standards ISO.

[9] **Corrigenda** [*korigénda* Lat., which should be corrected, from *corrigere* correct] – corrections, a list of printing and authorial errors with adequate corrections.

1980–86 The Netherlands carried out anthropometric measurements on a sample of around 10 000 people of both sexes and developed sizing tables for the clothing industry.

1981–82 Germany again organised anthropometric measurements of the female population, including some 10 000 women and girls.

1982 The British Office of Standardisation issued a series of standards for the designation of garment sizes, that is, BS 3666 (BS 3666, 1982) for women's garments, BS 3728 (BS 3728, 1982) for children's garments, and BS 6185 (BS 6185, 1982) for men's garments.

1983 Japan issued a standard sizing system for women's garments JIS L4005.

1983 The German Association for Women's Outerwear (DOB)[10] developed a sizing system, adapted to ISO standards. This sizing system encompassed nine body types classified according to height and build – tall, medium and short for height and slim, normal and heavy for build.

1986 Hungary developed a sizing system for women's garments MSZ 6100/1 (OHS, 1986; Dán and Déri, 1998), which defined two types of build: normal and heavy.

1988 The USA issued an anthropometric study, entitled ANSUR, for military personnel. Its aim was to define sizing standards for military uniforms and equipment. This investigation included 1774 male and 2208 female subjects (Ashdown, 1998).

1989 The European Association of Clothing Industry (AEIH) prepared a series of men's and women's body measurements, based on three size types and six other body measurements.

1989 The ISO/TC 133, at the International Organisation for Standardisation, issued the standard ISO 8559 (ISO 8559, 1989), dealing with garment construction, anthropometric surveys and body dimensions.

1990 Members of the Technical Committee of the European Association of Clothing Industry (AEIH), developed a set of tables of garment measurements.

1990 The British Office for Standardisation issued the standard BS 7231 which dealt with the anthropometric measurements of boys and girls, from infants to 16.9 years of age. The first part of the standard, BS 7231–1 (BS 7231–1, 1990), presented the information in tabular form whilst the second part, designated BS 7231–2 (BS 7231–2, 1990), gave recommendations for children's body measurements.

1991 A paper was published in Germany, entitled *New European Garment Sizing Tables (Neue Europa-Größen-Tabellen für Bekleidung)*

[10] **DOB** [ger. *D(amen)*-O(ber)b(ekleidungs-Industrie)] – Acronym German retail women's outerwear.

(Rausch, 1991). The tables were based on European studies and synchronised within European standards. Clothing manufacturing associations in Belgium, Denmark, Germany (with the exception of men's garments), Finland, Greece, the Netherlands, Norway, Portugal, Sweden, and Switzerland supported the tables, whilst France, Great Britain, Spain, and Finland opposed them.

1991 The ISO/TC 133 Technical Committee at the International Organisation for Standardisation issued technical information ISO/TR 10652 (ISO/TR 10652, 1991), entitled *Standard garment sizing systems*.

1992–94 Japan was probably the first country to organise comprehensive anthropometric measurements using 3D-body scanners. This investigation involved some 34 000 people (around 19 000 males and 15 000 females) aged between 7 and 90. The study found the average Japanese to be 10 cm taller than had been the case 100 years earlier (NIBHT, 1997).

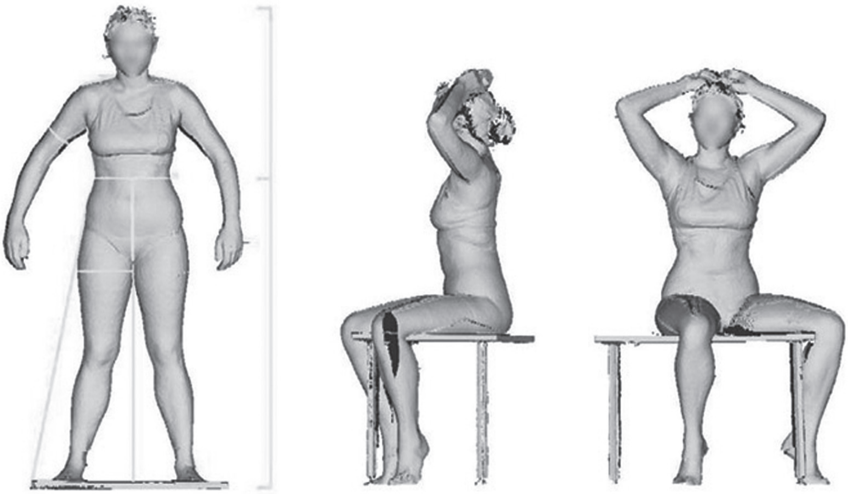
1994 A committee of the American Society for Testing and Materials (ASTM[11]) issued an up-to-date standard D5585–94, based on new anthropometric measurements but which also took into account previous experiences and USA market investigations (Ashdown, 1998).

1994 The German Association for Women's Outerwear (DOB) developed a new sizing table for women's outerwear which incorporated 24 body measurements.

1995 The USA organised anthropometric measurements of more than 6000 women aged 55 and over. This revealed that the values at the time did not match the actual sizes of older people and that in consequence, many garments did not offer a proper fit. A new standard was designed for the female population of this age group D5585–95 (ASTM D5585–95, 1995; Goldsberry, 1996a, 1996b).

1998 A working group of the CAESAR (Civilian American and European Surface Anthropometry Resource) project, which investigated weight, ethnic heritage, gender, geographic and socio-economic status of people, obtained more than 10 000 anthropometric measurements recorded in South America, the Netherlands, and Italy. This investigation used Cyberware 3D-body scanners and incorporated three records for each person, one in a standing and two in a sitting position, Fig. 2.3

[11] **ASTM** [A(merican) S(ociety for) T(esting and) M(aterials)], is an international standards organisation that develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems, and services. ASTM, founded in 1898 as the American Section of the International Association for Testing and Materials, pre-dates other standards organisations such as BSI (1901), DIN (1917), etc. Since 2001 it has been known as ASTM International.



2.3 Three body postures (Ashdown *et al.*, 2007).

(Robinette *et al.*, 1999; Ashdown *et al.*, 2002, 2007). The CAESAR study (a survey of body measurements for people aged between 18 and 65), is a collaborative effort with partners from several countries across many industries.

1999 Anthropometric measurements in the Netherlands began in August 1999. Entitled NedScan. These were part of the CAESAR project and involved 1255 male and female subjects aged between 18 and 65. A Vitronic 3D-body scanner was used to take the measurements (Robinette *et al.*, 2002).

1999–2004 The Centre for 3D Electronic Commerce was established in Great Britain. This had three important projects: virtual shopping, custom-made garments, and a national sizing survey, known as SizeUK. These were the first comprehensive anthropometric measurements performed in Great Britain since 1950. The measurements were undertaken in eight different areas of the country and involved 5000 male and 5000 female subjects. They were performed using a $[TC]^2$ scanner, which enabled 140 automated measurements to be taken for each person (Bougourd and Treleaven, 2002).

The results of the survey showed that over 60% of UK shoppers had difficulty finding clothes to fit and that the average female waist size had increased by 16.5 cm since the 1950s (Anon., 2011a).

2001–04 The European Committee for Standardisation (CEN), which had started the process of designing a new, modern system of garment size designation in 1996, issued the European standard size designation of clothes EN 13402 (ENCS, 2006). The first part of the standard, EN 13402–1 (EN 13402–1, 2001), issued in 2001, dealt with terminology, definitions, and measurement procedure. The second part, designated EN 13402–2 (EN 13402–2, 2002), was issued in 2002 and dealt with primary and secondary dimensions, whilst the third part of the standard, EN 13402–3 (EN 13402–3, 2004), describing measurements and the intervals at which they were to be taken, was issued in November 2004. The fourth part, EN 13402–4 (prEN 13402–4, 2005), which deals with the coding system, is still in preparation. The standards were prepared by the Technical Committee of the European Committee for Standardisation CEN/TC 248, Textile and Textile Products.

2000–02 Anthropometric measurements were carried out in Italy as part of the project CAESAR, under the title of NedScan.

2002–03 Employing a method and procedure similar to that of the British SizeUK, America performed anthropometric measurements on 10 800 people at 13 different locations in the USA (Anon., 2010a).

2004 Mexico organised comprehensive national anthropometric measurements using the $[TC]^2$ scanner, which involved a sample of 6600 male and female subjects.

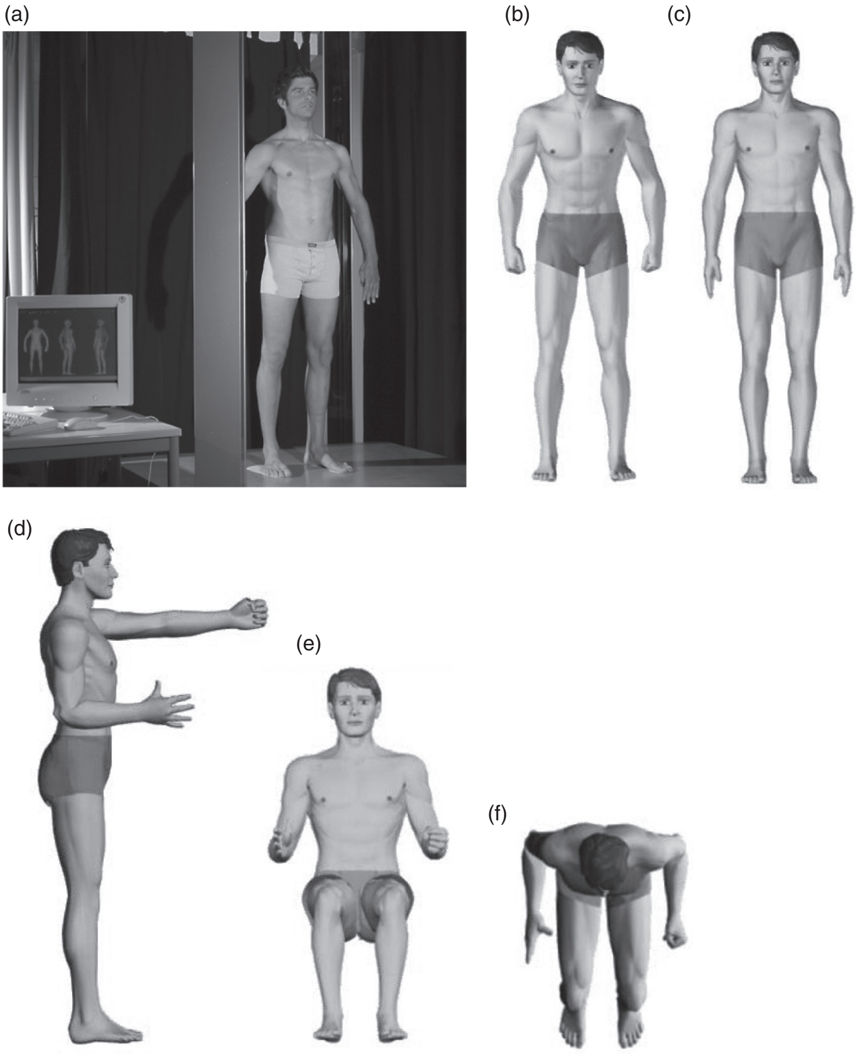
2004 The Republic of South Africa initiated a project entitled African Body Dimension (ABD), carrying out anthropometric measurements to meet the needs of their clothing and textile industries (Pinkie *et al.*, 2010).

2004–05 In Croatia, the technological research and development project Croatian Anthropometric System (HAS), carried out comprehensive measurements of 30 866 subjects at 20 municipalities in Croatia and in the capital city of Zagreb. The measurements were intended to provide a foundation for the design of new garment and footwear sizing systems (Ujević *et al.*, 2006).

2006 IFTH, the French Textile and Clothing Institute published the results of the French Measurement Campaign, for which it acted as project manager. The objective was to measure a representative sample of the population throughout France. 11 562 people (men, women and children), from 5 to 70 years of age, were measured. The results showed the morphology of the French population had changed. Over a period of 36 years, women had become taller (from 160.4 to 162.5 cm) and had increased from a size 38 to a size 40. Men were taller (by 6.9 cm) and heavier (by 5.4 kg) (Anon., 2012b).

2006 An anthropometric survey of 1000 women and 500 men aged between 18 and 24 was conducted by D. Gupta from the Indian Institute of Technology in Delhi (Gupta *et al.*, 2006; Gupta, 2010).

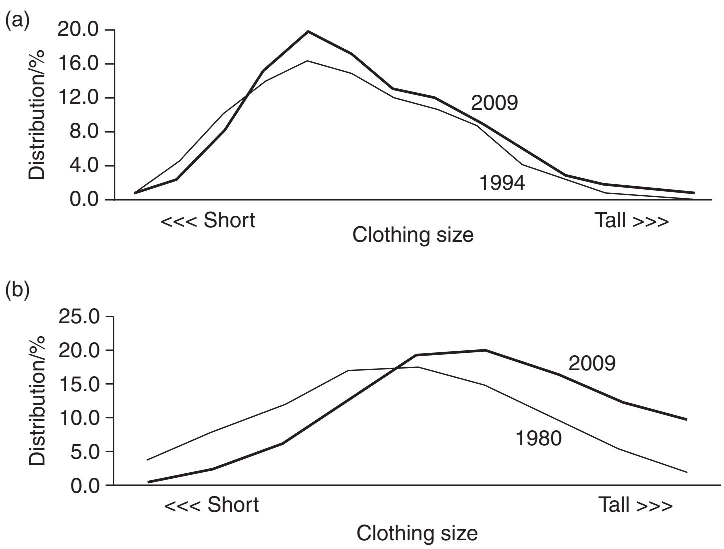
2007–09 The Hohensteiner Institut Bönnigheim, together with the company Human Solutions, began a project of taking representative anthropometric measurements, (named SizeGERMANY) on 1st of July. The project was supported by the German clothing industry, clothing retail companies and the Association of Clothing Industries. The measurement phase ended on 31 October 2008, after the measurements of 13 362 men, women and children in an age range of 6–87 years had been recorded. The measurements were taken in four postures, three standing and one sitting, Fig. 2.4, using the Human



2.4 Anthropometric measurements using the Human Solutions 3D-body scanner (Anon., 2009b): (a) 3D-body scanner, (b), (c) and (d) standing postures, (e) and (f) sitting postures.

Solutions 3D-body scanner (Anon., 2009a, 2009b). The resultant data were processed for statistical analysis in the two main application sectors of fashion and ergonomics to determine significant changes in body measurements. The last representative size survey for women was carried out in Germany in 1994. The following increases on the average values gathered in 1994 were identified for women between the ages of 14 and 70 years, independently of clothes size: height around 1.0 cm; chest 2.3 cm, waist 4.1 cm and hips 1.8 cm, Fig. 2.5a. In men, the average increases on measurements gathered in the representative size survey of 1980 were: height around 3.2 cm, chest 7.3 cm, waist 4.4 cm and hips 3.6 cm, Fig. 2.5b (Anon., 2009b). It was also established that body forms change with age. An 80-year-old and a 25-year-old may both wear size 38 and be of equal height, but their figures will differ.

2009–11 The UK government sponsored Shape GB – a major research project which measured children seven years after the previous national sizing survey had measured men and women. Shape GB is the first large-scale project to use 3D-body scanners to measure children across the country. The aim was to measure at least 6000 boys



2.5 Comparing the last anthropometric measurements with those from the 1994s (for women), respectively from the 1980s (for men) (Anon., 2009b). (a) Women's clothing size – distribution by population (size survey 1994 and 2009). (b) Men's clothing size – distribution by population (size survey 1980 and 2009). Source: SizeGermany.

and girls aged between 4 and 17 during 2010. Shape GB is based on the fact that body shape may be as significant as a size chart in the design and manufacture of children's clothes (Anon., 2011b). The Shape GB project will provide a clearer guide to children's height and shape and the manner in which sizes may need to be changed to create better fitting clothes for specific age ranges.

2.3 European and international sizing systems

Various systems are currently in use for designating the size of clothes. Most countries have defined standards according to their own criteria. The sizing systems which have developed in European countries differ considerably. Most are defined by height and the differences between chest, waist and hip girth. The size designation of clothes is generally based on height, defined as short, regular or tall. This is further defined by three anthropometric dimensions: chest, waist, and hip girth, whilst the figure type may be slim, normal, or stout.

In the 1970s, the International Organisation for Standardisation (ISO) issued a series of standards representing the starting point and foundation for a common system of garment sizing and designation. The formulation of the ISO 3635 (ISO 3635, 1981) standard, and the standard ISO 8559 (ISO 8559, 1989), and ISO 9407 (ISO 9407, 1991) foundations were built on a universal system of body measurements to meet the needs of the clothing and footwear industries. The Technical Committee ISO/TC 133 formulated a system of sizing and size designation and introduced nine further standards for size designation in addition to ISO 3635 and ISO 8559. These were:

- ISO 3636 Size designation of clothes – Men's and boys' outerwear garments,
- ISO 3637 Size designation of clothes – Women's and girls' outerwear garments,
- ISO 3638 Size designation of clothes – Infants' garments,
- ISO 4415 Size designation of clothes – Men's and boys' underwear, nightwear and shirts,
- ISO 4416 Size designation of clothes – Women's and girls' underwear, nightwear and shirts,
- ISO 4417 Size designation of clothes – Headwear,
- ISO 4418 Size designation of clothes – Gloves,
- ISO 5971 Size designation of clothes – Pantyhose,
- ISO 7070 Size designation of clothes – Hosiery.

The same committee also issued a Technical Report ISO/TR 10652[12] (ISO/TR 10652, 1991) entitled *Standard sizing systems for clothes*. This established a body-sizing system for use in compiling standard clothing sizes for infants, men, boys, women and girls.

New European tables of clothing sizes were presented in the same year and accepted by the clothing manufacturing associations of European countries, with the exception of France, Great Britain, Spain, and Finland (Rausch, 1991). The suggested sizing system included tables of body measurements for garments for adults and children of both sexes as well as for infants' garments. Each size was defined by up to seven body dimensions for both women and men, such as body height, chest and waist girth, arm length, crotch length and waist height. The same height indicates the same body (build) type in women's and men's sizing systems, but with differing chest girths. The height changed in sizing systems intended for girls, boys, children and infants.

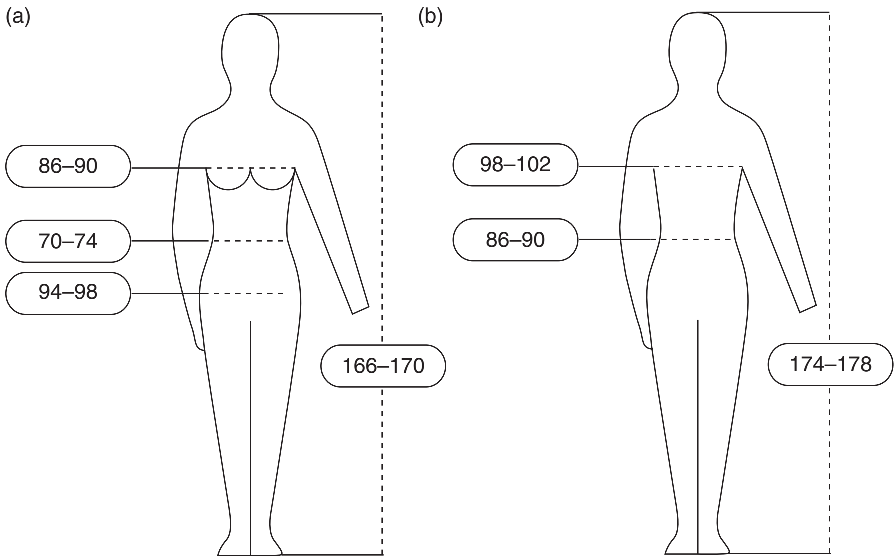
In 1996, the European Committee for Standardisation (CEN) began preparations for a modern system of size designation, which resulted in the EN 13402 standard. This consists of four parts: EN 13402–1 (EN 13402–1, 2001), relating to terminology, definitions, and body measurement procedure, EN 13402–2 (EN 13402–2, 2002), relating to primary and secondary dimensions, EN 13402–3 (EN 13402–3, 2004), relating to measurements and intervals, and EN 13402–4, relating to the coding system used.

The formulation of the first three parts of the standard presents definitions and terminology. The procedures for taking body measurements define primary and secondary dimensions and the intervals between sizes. The fourth part of the standard, which is still in preparation, will define those methods of coding sizes which are necessary for computerised data processing, raw procurement, sales, changes, and product analysis.

Taking the standard EN 13402 as a basis, a system of size designation of clothes was developed, having four sources (ENCS, 2006):

- body measurements,
- metric system,
- data obtained by new anthropometric surveys of the European population, to be completed by the end of the nineties,

[12] This document is being issued in the type 2 Technical Report series of publications as a "prospective standard for provisional application" in the field of sizing systems for clothes because there is an urgent need for guidance on how standards in this field should be used to meet an identified need.



2.6 An example of a pictogram used to designate (a) women's and (b) men's garments.

- the introduction of pictograms, that is, representation of a human silhouette, on which the characteristic sizes of products ready for sale should be presented, Fig. 2.6 (EN 13402–3, 2004).

The size designation system is based on body measurements and not on those of a garment. Body measurements indicate garment sizes, whilst particular garment measurements are normally determined by designers and manufacturers who will make appropriate allowances to accommodate the type, position of wear, style, cut, and fashion elements of a garment.

The standard defines the difference between primary body dimensions (measured in centimetres, which should be used to designate the size of a garment for the consumer), and secondary dimensions (those body measurements in centimetres – or in the case of pantyhose (tights), the body mass in kilograms – which may be additionally used to designate the size of a garment for the consumer). Primary and secondary dimensions are defined as shown in Table 2.1 (EN 13402–2, 2002). These body measurements provide the basis for the designation of clothing sizes in garment types as diverse as jackets, skirts, underwear, corsetry and headwear. They are independent of the product. Only the body height is used as the primary dimension for infants and constitutes the basic size designation system.

Table 2.1 Primary and secondary dimensions in garments

		Garments type				
		Dimensions	Men	Women	Boys	Girls
Outer garments	Jackets	Primary	Chest girth	Bust girth	Height	Height
		Secondary	Height Waist girth	Height Hip girth	Chest girth	Bust girth
	Suits	Primary	Chest girth Waist girth	Bust girth	Height	Height
		Secondary	Height, Inside leg length	Height Hip girth	Chest girth	Bust girth
	Overcoats	Primary	Chest girth	Bust girth	Height	Height
		Secondary	Height	Height	Chest girth	Bust girth
	Trousers/shorts	Primary	Waist girth	Waist girth	Height	Height
		Secondary	Height Inside leg length	Height Hip girth Inside leg length	Waist girth	Waist girth
	Skirts	Primary	–	Waist girth	–	Height
		Secondary	–	Height Hip girth	–	Waist girth
	Dresses	Primary	–	Bust girth	–	Height
		Secondary	–	Height Hip girth Waist girth	–	Bust girth
	Knits: Cardigans, sweaters, T-shirt	Primary	Chest girth	Bust girth	Height	Height
		Secondary	Height	Height	Chest girth	Bust girth
	Shiers	Primary	Neck girth	–	Height	–
		Secondary	Height, Arm length	–	Neck girth	–

	Blouses	Primary	–	Bust girth	–	Height
		Secondary	–	Height	–	Bust girth
Underwear	Vest	Primary	Chest girth	Bust girth	Height	Height
		Secondary	Height	Height	Chest girth	Bust girth
	Underpants	Primary	Waist girth	Waist girth	Height	Height
		Secondary	Height	Height, Hip girth	Waist girth	Waist girth
	Pyjamas Ladies' nightdresses	Primary	Chest girth	Bust girth	Height	Height
		Secondary	Height Waist girth	Height Waist girth Hip girth	Chest girth	Bust girth
	Swim-suit/wear and bodies	Primary	Waist girth	Bust girth	Height	Height
		Secondary	Height Chest girth	Height Hip girth Underbust girth	Chest girth Waist girth	Underbust girth Bust girth
Corsetry	Bras	Primary	–	Underbust girth Bust girth	–	Underbust girth Bust girth
		Secondary	–	Cup size[a]	–	Cup size
	Corsetry/upper and full body	Primary	–	Underbust girth Bust girth	–	–
		Secondary	–	Height, Hip girth Waist girth	–	–

[a] Cup size – the difference between the underbust girth and the bust girth.

2.4 ISO clothing sizing systems

In creating a sizing system, a population is first divided into different body types based on dimensions such as height. The same height in women's and men's sizing systems defines the same body type, although with differing chest girths. When dealing with sizing systems for boys, girls, children and infants, the body height will change.

2.4.1 Women's garment-sizing system

The standard sizing system for women is based on chest girth as a primary dimension and on body height varying from 156 to 188 cm, Table 2.2 (EN 13402–3, 2004). The interval among individual sizing numbers is 4 or 8 cm (156–160–164–168–172–176–180–184–188). These intervals are standardised, which enables individual countries or clothing manufacturers to decide which of the two intervals to use, the recommendation being to use an interval of 8 cm for general use, and 4 cm for trousers. For example:

- If a height of 168 cm is selected with an interval of 8 cm, the range[13] on the pictogram will be designated as 164–172.
- If a height of 168 cm is selected with a 4 cm interval, the range on the pictogram will be designated as 166–170, Fig. 2.6.

The standard sizing system for women is within a chest girth of 76–152 cm. The interval between individual sizes is 4 cm up to a chest girth of 104 cm, and 6 cm above 104 cm. The interval for waist girth is 4 cm between 60 and 88 cm, and 6 cm for a waist measurement above 88 cm.

2.4.2 Men's garment-sizing system

The standard sizing system for men is based on chest girth and body height as the primary dimensions with heights ranging from 156 to 200 cm (EN 13402–3, 2004). The interval between individual sizes may be either 4 or 8 cm (156–160–164–168–172–176–180–184–188–182–196–200). The standard enables a particular country or clothing manufacturer to select intervals of 4 or 8 cm, whilst recommending the use of an 8-cm interval in general, and 4 cm for trousers.

Body sizes for men's garments begin with a chest girth of 84 cm, with an interval of 4 cm between individual sizes, up to a chest girth of 120 cm, and

[13] **Range** – is calculated by using one half plus or minus interval from the primary or secondary dimension measurement. If the interval is 1.5 cm or less, no range will be shown on the pictogram. All ranges on the pictogram will be rounded down to whole numbers. In case of weights, the range is shown in whole numbers.

Table 2.2 Standard heights for women dimensions in centimetres

Interval	Standard heights for women h_w/cm								
	← 156	160	164	168	172	176	180	184	188 →
	Range								
8 cm	—	156–164	—	164–172	—	172–180	—	180–188	—
4 cm	154–158	158–162	162–166	166–170	170–174	174–178	178–182	182–186	186–190

an interval of 6 cm above a chest girth of 120 cm. Garment sizes end with a chest girth of 144 cm. The interval for other size types is 4 cm for waist girth up to 108 cm and an interval of 6 cm above 108 cm.

2.4.3 Garment-sizing systems for infants, girls and boys

This sizing system is based on body height as the primary dimension and not on age, as height differs greatly between countries, resulting in considerable variations in height within age groups. The standard recognises the differences between (EN 13402–3, 2004):

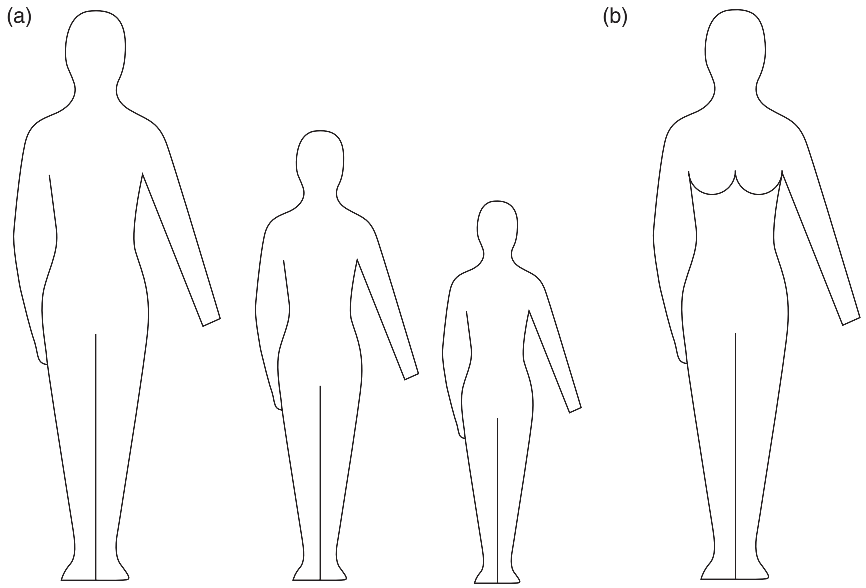
- body sizes for infants' garments, starting with a body height of 44 cm and ending with a height of 74 cm (the interval between individual body heights being 3 cm);
- body sizes for girls' and boys' garments, starting with a body height of 80 cm and ending with a height of 194 cm (the interval between individual body heights being 6 cm).

2.5 European designation of clothing sizes

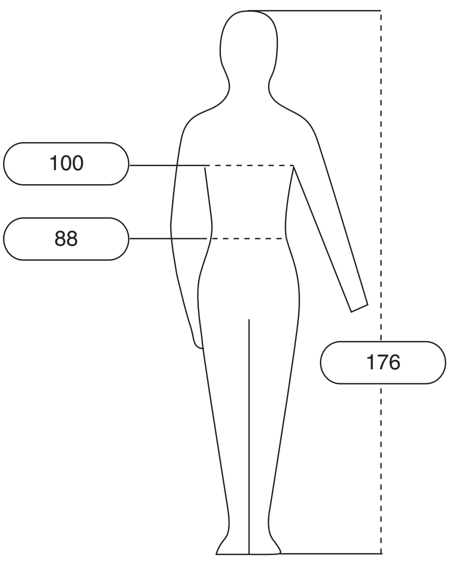
The system for size designation[14] is based on requirements imposed by the standards EN 13402–1 (EN 13402–1, 2001), EN 13402–2 (EN 13402–2, 2002), and EN 13402–3 (EN 13402–3, 2004), and on the representation of individual characteristic measurements on a pictogram, Fig. 2.7. A pictogram is a symbolic representation of a body silhouette, with the positions and values of selected dimensions noted. A standard pictogram is used to represent these values, Fig. 2.7a. A modified pictogram is used for some body measurements. This is a standard pictogram with the position of the chest indicated by two concave lines, showing the position of the control dimensions of the girth under the breasts (EN 13402–1, 2001).

The control dimensions shown on a pictogram depend upon the type of garment. There are two types of control dimensions defining garment size. These are the primary, or basic dimension, and one or more secondary dimensions. Chest girth is the more commonly used primary dimension in women's and men's garments, whilst for children it is body height. To standardise the presentation of body dimensions on a pictogram, all the measurements relating to the girths of particular body parts are marked in a circle on the left side of the pictogram, whilst the measurements relating to the height or length of a body part are placed in a circle on the right side of the pictogram (Fig. 2.8).

[14] **Size designation** – the official method of body size labelling on a garment, either by pictogram or by indicating the appropriate control dimensions and their numerical values.



2.7 Example of a standard and modified pictogram. (a) Standard pictogram and (b) modified pictogram.



2.8 An example of size designation of clothes.

Table 2.3 A list of letter codes related to chest girth

Mark	Meaning	Chest girth G_{Ch}/cm	
		Men	Women
XXS	Extra extra small	70–78	66–74
XS	Extra small	78–86	74–82
S	Small	86–94	82–90
M	Medium	94–102	90–98
L	Large	102–110	98–106
XL	Extra large	110–118	107–119
XXL	Extra extra large	118–129	119–131
3XL	Extra extra extra large	129–141	131–143

An overall review of anthropometric surveys and measuring procedures is presented in the standard ISO 8559 (ISO 8559, 1989). This includes 26 horizontal dimensions, relating to the girths of particular body parts, 27 vertical dimensions, relating to body heights or the lengths of particular body parts, as well as two special measurements – body mass measured in kilograms and shoulder slope in degrees.

2.5.1 The letter codes

The standard also defines letter codes (EN 13402–3, 2004; ENCS, 2006) for those garments that allow higher intervals between sizes, namely where the letter code includes two bust or chest sizes, that is, two intervals. These letter codes are based on girth (bust, chest) and on the average height or a specific choice of height. The standard does not define these codes for children's garments. A letter code consists of two numeric values as intervals of chest girth. A list of letter codes relating to chest girth can be seen in Table 2.3.

Where there is a need for larger sizes, the type of garment size may be extended from XXS and/or from 3XL. Letter codes and appropriate body size dimensions for men's and women's garment are presented in Table 2.4 (EN 13402–3, 2004). Letter codes for women's garments consist of the sum of the interval of two numeric bust girths. For men's garments, the code is the sum of the interval of two numeric chest girths.

2.6 The JUS clothing sizing systems

Slovenia still uses a garment-sizing and designation system based on the requirements of the JUS[15] standard. It is based on body height and figure type

[15] **JUS** [*Ju(goslovanski) s(tandard)*] – former Yugoslav industrial standard.

Table 2.4 Letter codes for women's and men's garments

Letter code for women/dimensions in cm

Chest girth	← 68	72	76	80	84	88	92	96	100	104	110	116	122	128	134	140 →
Letter code	← XXS		XS		S		M		L		XL		XXL		3XL →	
Range	66–74		74–82		82–90		90–98		98–106		107–119		119–131		131–143	

Note: The interval is 4 cm up to the chest girth of 104 cm, above 104 cm the interval changes from 4 to 6 cm.

Letter code for men/dimensions in cm

Chest girth	← 72	76	80	84	88	92	96	100	104	108	112	116	120	126	132	138 →
Letter code	← XXS		XS		S		M		L		XL		XXL		3XL →	
Range	70–78		78–86		86–94		94–102		102–110		110–118		118–129		129–141	

Table 2.5 Figure types according to body height

Type of figure/height	Body height h/cm	
	Male	Female
Extremely short	156–160	152–156
Short	163–167	158–162
Medium	170–174	164–168
Tall	177–181	170–174
Extremely tall	184–188	176 and more

or build. Articles of clothing are designated using a mark representing body height and figure type (JUS F.G0.001, 1979; JUS F.G0.002, 1979). The standard recognises five types defined by height for males and females, as shown in Table 2.5. Each group is divided into three figure types: slim, normal and full.

2.6.1 Men's garments

Size designation for men's garments is based on a mark which represents the figure type, the chest girth, and body height. The standard recognises a slim figure (marked 7), a normal figure (no mark) and a full figure (marked 0) (JUS F.G0.003, 1979). Body height is not designated by any special mark, but it is defined by the value of the chest girth (G_{Ch}), or its multiplier/divisor. Thus, an extremely short figure is designated as 1/8 G_{Ch}, a short figure as 1/4 G_{Ch}, a medium figure as 1/2 G_{Ch}, a tall figure as G_{Ch}, and an extremely tall figure as 2 G_{Ch}.

Garment size is designated as A–B, where the mark A is the figure type and B denotes chest girth and body height, for example, 7–52 is the mark for a man's jacket, intended for a male of medium height and slim figure, with a chest girth of 104 cm. Garment sizes for beach-robes and pyjamas are designated with a mark which represents half the chest girth and the figure height, which may be short (mark 1), medium (no marks) or tall (mark 3), for example: 52–1, 52 or 52–3.

Men's shirts carry a mark describing the neck girth in centimetres and the body height. For example: 37–1, 37 or 37–3. Garment size for men's underpants carry a mark describing waist girth and body height, for example, 90–1, 90 or 90–3, whilst the mark for short underpants is included in the waist girth.

2.6.2 Women's garments

Size designation for women's garments is also based on a mark representing the figure type, chest girth, and body height. Chest girth is expressed by a so-called conventional number. This number represents a chest girth reduced by 12 cm for girths between 88 and 104 cm, and by 14 cm for chest girth above 104 cm (JUS F.G0.004, 1979). The size designation mark uses the conventional number or its divisor/multiplier, and depends on body height. For extremely short figures it is expressed as 1/8 of the conventional number, for short ones as 1/4, for medium as 1/2, for tall figures it is equal to the conventional number and for extremely tall it is double the value of the conventional number. The standard recognises three figure types; slim (marked 7), normal (no mark) and full figure (marked 0).

Women's garment sizes are marked with A–B, where the mark 7–38, for example, indicates a garment for a woman of medium height, slim figure, and a chest girth of 88 cm, and a garment designated 7–48 is intended for a woman of medium height and a chest girth of 110 cm. Garment sizes for panties, corsets and girdles are designated with a mark representing waist girth in centimetres, that is 92. Bras and corsets with incorporated bras, have a mark representing breast size, the mark A standing for small and undeveloped, B medium, C strong and D heavy, as well as a mark denoting the under-breast girth, for example: A/80, C/80.

2.6.3 Boys' garments

Garments for boys between the ages of 2 and 16 are designated by a mark which includes age and body height in centimetres. The garment size is expressed using the mark A/B, where A denotes age (from 3 to 16 years of age) and B is the body height in centimetres. Thus a garment for a boy 9 years old and 132 cm in height, carries the mark 9/132 (JUS F.G0.005, 1979). Shirts display a mark which expresses the neck girth and underpants the waist girth.

2.6.4 Girls' garments

Sizing for girls' garments is designated in the same way as for boys. The designation mark consists of the age (from 2 to 16 years) and the body height in centimetres, whilst the size number of the garment is expressed with the mark A/B, that is, 12/146 (JUS F.G0.006, 1979).

2.6.5 Infants' garments

For infants up to 1 year of age, the size designation is expressed by the length (for suckling infants) or body height, that is, 62 (JUS F.G0.007, 1979).

2.7 Conclusions

Clothing quality is defined both through its aesthetic and functional properties and by the sense of well-being imparted by a suitable drape and fit. The provision of garments to fit a population is a critical issue for designers and manufacturers of clothing. This is of equal importance, both during the engineering planning of new collections and in the introduction of new technologies for manufacturing by individual measurements to meet customer requirements. This chapter presents an overview of sizing systems and designation systems which have been developed to provide a range of sizes to fit a population. A sizing system may be as simple as one-fits-all or sufficiently complex to provide individually custom-fitted clothing.

2.8 References

Anon. (1970), *Körpermaβtabellen und Maβanteiltabellen für Damen- und Mädchen-Oberbekleidung*, Bönnigheim, Forschungsinstitut Hohenstein, Schloβ Hohenstein.

Anon. (1993), *1902 Edition of the Sears*, Roebuck & Co. Catalog, The Wonderful World of Turn of the Century Commerce, the Likes of which will never be see again. Published 12 October 1993 by Gramercy (first published 12 October 1902).

Anon. (2002), *Big dictionary of foreign words* (in Slovenian), editor: M. Tavzes et al., Ljubljana, published by Cankarjeva založba.

Anon. (2008a), *Maβnehmen im Dienst der Mode*, Bönnigheim, Hohensteiner Institute, Internationales Textilforschungszentrum, Presse Info, September 2008.

Anon. (2008b), *The 1902 Sears, Roebuck Catalog,* The Wonderful World of Turn of the Century Commerce, the Likes of which will never be see again. If we're lucky, Available from: http:// 1902sears.blogspot.com/2006_04_01archive.html [Accessed 15 September 2008].

Anon. (2009a), *SizeGERMANY*, Hohenstein, Die Hohenstein Institute.

Anon. (2009b), Neuen Konfektionsgröße, Projekt SizeGERMANY, Forschung + Entwicklung, Forward textile Technologies, Juni 2009, 78–79.

Anon. (2010a), Size USA. Available from: URL:http://www.sizeusa.com/ [Accessed 4 February 2010].

Anon. (2010b), The German representative size survey SizeGERMANY, Available from: http://www.hohenstein.de/ximages/1399929_sgabschlus.pdf [Accessed 15 January 2011].

Anon. (2011a), Size UK, Sizemic Data – Size Survey Data. Available from: http://www.sizemic.eu/products-and-services/size-survey-data.html [Accessed 10 January 2011].

Anon. (2011b), SHAPE GB – The National Childrenswear Survey – Home. Available from: http://www.shapegb.org/home [Accessed 15 January 2011].

Anon. (2012a), Tales of Statisticians: Adolphe Quetelet. Available from: http://www.umass.edu/wsp/statistics/tales/quetelet.html [Accessed 20 January 2012].

Anon. (2012b), French Measurement Campaign. Available from: http://www.ifth.org./innovation-textile/IFTH-pagesHTML/measurement-french-measurement-campaign-french-measurement-campaign.htm [Accessed 10 January 2012].

Ashdown, S. P. (1998), An investigation of the structure of sizing systems – a comparison of three multidimensional optimized sizing systems generated from anthropometric data with the ASTM Standard D5585–94, *International Journal of Clothing Science and Technology*, **10** (5), 324–341.

Ashdown, S. P., Loker, S. and Andelson, C. (2002), *Use of Body Scan Data to Design Sizing Systems Based on Target Markets*, Annual Report S01-CR-01, National Textile Centre.

Ashdown, S. P., Loker, S. and Rucker, M. (2007), NTC Project: S04-CR01 *Improved Apparel Sizing: Fit and Anthropometric 3D Scan Data*, National Textile Center, Annual report, November 2007.

ASTM D5585 – 95:1995 Standard Tables of Body Measurements for Women Aged 55 and Older (All Figure Types).

Balaban, V., Valačić, K., Knez, B., Dimitrijević, B., Šećerov, B. and Stokanović, M. (1963), *Study of Experimental Anthropometric Measurements of the Population of Vojvodina for the Needs of Garment Industry* (in Serbian), Belgrade, Yugoslav Department of Standardisation and Federal Chamber of Commerce.

Boughey, R. (1978), Developments in size labelling of women's garments, *Journal of Consumer Studies & Home Economics*, **2** (4), 303–312.

Bougourd, J. P. and Treleaven, P. C. (2002), *Capturing the Shape of a Nation: Size UK*, IFFTI International Conference, Hong Kong.

BS 3666:1974 Size Coding Scheme for Women's Outwear.

BS 3666:1982 Specification for size designation of women's wear.

BS 3728:1982 Specification for size designation of children's and infants' wear.

BS 5511:1977 Size designation of clothes – Definitions and body measurement procedure.

BS 6185:1982 Specification for size designation of men's wear.

BS 7231–1:1990 Body measurements of boys and girls from birth up to 16.9 years, Information in the form of tables.

BS 7231–2:1990 Body measurements of boys and girls from birth up to 16.9 years, Recommendations of body dimensions for children.

Chun-Yoon, J. and Jasper, C. R. (1993), Garment-sizing systems: An international comparison, *International Journal of Clothing Science and Technology*, **5** (5), 28–37.

CS151–50:1945 *Body Measurements for the Sizing of Apparel for Infants*, Babies, Toddlers and Children, The Mail Order Association of America.

CS151–50:1948 *Body Measurements for the Sizing of Apparel for Infants, Babies, Toddlers and Children* (For the Knit Underwear Industry), The Mail Order Association of America.

CS 215–58:1958 *Body Measurements for the Sizing of Women's Patterns and Apparel*, The Mail Order Association of America, 1958.

Dán, Z. and Déri, Á. (1998), Gyártmánytervezés I. (Produktentwurf I.), Lehrmaterial von Lehrstuhl für Bekleidungsindustrie, Budapest, Hochschule für Leichtindustrie.

EN 13402–1:2001 Size designation of clothes – Part 1: Terms, definitions and body measurement procedure (ISO 3635:1981 modified).

13402–2:2002 Size designation of clothes – Part 2: Primary and secondary dimensions.

EN 13402–3:2004 Size designation of clothes – Part 3: Measurements and intervals.

ENCS (2006), 85B EN 13402 – A European Clothing Size Standard, February 21st, 2006. Available from: http:// www.85.info/en-13402-a-european-clothing-size-standard [Accessed 4 September 2008].

Fan, J., Yu, W. and Hunter, L. (2004), *Clothing Appearance and Fit: Science and Technology*, Cambridge, Woodhead Publishing Limited and CRC Press LLC.

Goldsberry, E., Shim, S. and Reich, N. (1996a), Women 55 years and older: Part I. Current body measurements as contrasted to the PS 42–70 data, *Clothing and Textiles Research Journal*, **14** (2), 108–120.

Goldsberry, E., Shim, S. and Reich, N. (1996b), Women 55 years and older: Part II. Overall satisfaction and dissatisfaction with the fit of ready-to-wear, *Clothing and Textiles Research Journal*, **14** (2), 121–132.

Gupta, D. (2010), Anthropometric Study of Young Indian Men for Garment sizing, *Research Journal of Textile and Apparel*, **14** (1), 82–89.

Gupta, D., Garg, N., Arora, K. and Priyadarshini, N. (2006), Developing body measurement charts for garment manufacture based on a linear programming approach, *Journal of Textile and Apparel, Technology and Management*, **5** (1), 1–13.

ISO 3635:1981 Size designation of clothes – Definitions and body measurement procedure.

ISO 3636:1977 Size designation of clothes – Men's and boys' outerwear garments.

ISO 3637:1977 Size designation of clothes – Women's and girls' outerwear garments.

ISO 3638:1977 Size designation of clothes – Infants' garments.

ISO 4415:1981 Size designation of clothes – Men's and boys' underwear, nightwear and shirts.

ISO 4416:1981 Size designation of clothes – Women's and girls' underwear, nightwear, foundation garments and shirts.

ISO 4417:1977 Size designation of clothes – Headwear.

ISO 4418:1978 Size designation of clothes – Gloves.

ISO 5971:1981 Size designation of clothes – Pantyhose.

ISO 7070:1982 Size designation of clothes – Hosiery.

ISO 8559:1989 Garment construction and anthropometric surveys – Body dimensions, first edition.

ISO 9407:1991, Shoe sizes – Mondopoint system of sizing and marking.

ISO/TR 10652:1991 Technical Report: Standard sizing systems for clothes, First edition.

JUS F.G0.001:1979 *Garments and Bodily Measures, Terms and Definitions of Pictograms and Bodily Measures* (in Slovenian), Belgrade, Federal Department of Standardisation.

JUS F.G0.002:1979 *Garments and Bodily Measures, The Use of Pictograms and Determining Bodily Measures* (in Slovenian), Belgrade, Federal Department of Standardisation.

JUS F.G0.003:1979 *Men's Garments, Sizing and Designation System* (in Slovenian), Belgrade, Federal Department of Standardisation.

JUS F.G0.004:1979 *Women's Garments, Sizing and Designation System* (in Slovenian), Belgrade, Federal Department of Standardisation.

JUS F.G0.005:1979 *Boys' Garments, Sizing and Designation System* (in Slovenian), Belgrade, Federal Department of Standardisation.

JUS F.G0.006:1979 *Girls' Garments, Sizing and Designation System* (in Slovenian), Belgrade, Federal Department of Standardisation.

JUS F.G0.007:1979 *Garments for Infants Up To 1 Year of Age, Sizing and Designation System* (in Slovenian), Belgrade, Federal Department of Standardisation.

JUS F.G0.008:1979 *Caps, Hats, Headwear and Similar Products, Sizing and Designation System* (in Slovenian), Belgrade, Federal Department of Standardisation.

JUS F.G0.009:1979 *Gloves, Sizing and Designation System* (in Slovenian), Belgrade, Federal Department of Standardisation.

JUS F.G0.010:1979 *Pantyhose and Hosiery, Sizing and Designation System* (in Slovenian), Belgrade, Federal Department of Standardisation.

Knez, B. (1994), *Construction Preparation in Garment Industry* (in Croatian), Zagreb, Faculty of Textile Technology, University of Zagreb.

NIBHT (1997), *Japanese Body Size Data 1992–1994*, Osaka, National Institute of Bioscience and Human Technology.

NIST (2011a), Standardization of Women's Clothing Sizes – NIST Virtual Museum. Available from: http://museum.nist.gov/exhibits/apparel/index.htm [Accessed 15 September 2011].

NIST (2011b), Standardization of Women's Clothing Sizes, Standards, Commercial Standard. Available from: http://museum.nist.gov/exhibits/apparel/com_std.htm [Accessed 15 September 2011].

NIST (2011c), Body Measurements for the Sizing of Apparel, The American Society for Testing and Materials ASTM. Available from: http://ts.nist.gov/ts/htdocs/210/ncsci/docs/womens-ps42–70.pdf [Accessed 15 September 2011].

O' Brien, R. (1939), *Children's Body Measurements for Sizing Garments and Patterns*, Bureau of Home Economics, U. S. Department of Agriculture, Washington, D. C. Misc. Publ. No. 365.

O' Brien, R. (1941), *Body Size Measurements of American Boys and Girls for Garment and Pattern Construction*, Bureau of Home Economics, U. S. Department of Agriculture, Washington, D. C. Misc. Publ. No. 366.

OHS (1986), The Office of Hungarian Standards, People's Republic-State Standard MSZ 6100/1 (Ruházati termékek méretnagyságának megadása az új európai szabványok szerint) Budapest.

Pinkie, E., Zwane, P. E., Sithole, M. and Hunter, L. (2010), A preliminary comparative analysis of 3D body scanner, manually taken girth body measurements and size chart measurements, *International Journal of Consumer Studies*, **34** (3), 265–271.

Pollock, W. B. (Philadelphia, PA) (1885), *Garment Measuring and Fitting Device*. U. S. Patent no. 320,496, 14 January 1884.

Porter, R., Porter, T. M. and Ross, D. (2003), *The Cambridge History of Science: The Modern Social Sciences*, Cambridge, Cambridge University Press, 88–97.

prEN 13402–4:2005 Size designation of clothes – Part 4: Coding system.

PS 42–70: 1970 Body Measurements for the Sizing of Women's Patterns and Apparel, National Bureau of Standards.

Rausch, W. (1991), Neue Europe-Größen-Tabellen für Bekleidung, Ende der babylonischen Verwirrung in Sicht? *Bekleidung + Wäsche / Bekleidung + Maschenware*, **43** (3), 12–17.

Robinette, K. M., Daanen, H. and Paquet, E. (1999), *The CAESAR Project: A 3-D Surface Anthropometry Survey*. Proceeding 3DIM'99 Proceedings of the 2nd international conference on 3-D digital imaging and modelling, Washington, IEEE Computer Society Washington, 380–386.

Robinette, K. M., Blackwell, S. and Daanen, H. (2002), *Civilian American and European Surface Anthropometry Resource (CAESAR)*, Final report AFRL-HE-WP-TR-2002–0169 (interim report for the period December 1997 to June 2002), Volume I, United States Rir Force. Research Laboratory.

Schierbaum, W. (1982), *Bekleidungs-Lexikon*, 2. erweiterte Auflage, Berlin, Fachverlag Schiele & Schön GmbH.

Schierbaum, W. (1993), *Bekleidungs-Lexikon*, 3. erweiterte Auflage, Berlin, Fachverlag Schiele & Schön GmbH.

SDPH (1921), *Anthropometric Tables Covering Measurement of Male and Female Children from 6 to 72 Months Old*, Illinois State Department of Public Health, Vol. VII.

Spatz, C. (2011), *Basic Statistics: Tables of Distributions*, Tenth Edition, Belmont, Wadsworth Cengage Learning.

Swearingen, E. (1999), *Theoretical Model for Apparel Design Curriculum: Fit Satisfaction, Body Cathexis and Creativity*, M. Sc. Thesis, Fresno, California State University.

Ujevi , D., Rogale, D., Hrastinski, M. and Szirovicza, L. (2006), *Croatian Anthropometric System, A Basis for New Croatian Standards for Garment and Footwear Sizes*, Zagreb, Faculty of Textile Technology, University of Zagreb.

Whitacre, J. and Grimes, E. T. (1959), Some body measurements of native-born white children of seven to fourteen years in different climatic regions of Texas, *JSTOR: Child Development*, **30** (2), 177–209.

Workman, J. E. (1991), Body measurement specifications for fit models as a factor in clothing size variation, *Clothing and Textiles Research Journal*, **10** (1), 31–36.

3
Key issues in developing a garment collection

DOI: 10.1533/9780857097835.53

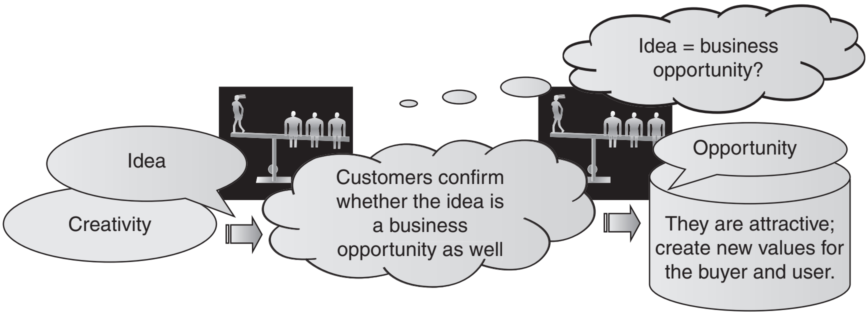
Abstract: This chapter presents an overview of garment collection development. It begins with the general requirements of product development. Methods of garment collection development are then explained. These include the concept of a collection, quality targets, trademarks and their role, followed by collection development management and control. The chapter includes a case study on the design of protective clothing. Finally, the preparations required for successful participation at fashion trade fairs are explained.

Key words: new product, clothing, collection development, functional protective clothing, fashion trade fair.

3.1 Introduction

Collection development is an important stage of clothing manufacture. Good design is a key factor throughout the fashion industry and is essential in maintaining the leading position Europe holds in global clothing manufacturing. In today's market it is necessary to adapt quickly to global requirements as there are no predominant fashion trends which change from season to season. Fashion trends are now defined more by young people around the world than by seasonal collections produced by major fashion houses. The trend has clearly shifted towards increasing the number of collections. It is therefore only a matter of time before continuous collections will be created. The role of the fashion designer and his/her creativity therefore takes on a new significance, since continuous change requires creative potential which can be quickly transformed into making clothing available on the high street.

G. Simmel (2000) wrote at the beginning of the twentieth century: 'Fashion is nothing more than one of the specialised forms among numerous life forms through which we combine our wish to attain social equalisation and the wish to be individual and different'. His ideas were based on perceiving the attraction of fashion as lying in the contrast between its widespread nature and the speed with which it tends to change, and the breadth of its scope when contrasted with an emphasis on individual tastes and preferences. The



3.1 Schematic representation of idea as a business opportunity.

fashion industry must provide products which customers want. The role of garment marketing is important here. The word 'marketing' denotes an entire business philosophy which seeks to match a business' resources and the design, manufacture, sales and advertising of its products with the needs of the market. It depends on empathy with the views of existing or potential customers. Fashion marketing is the application of this business philosophy, centred on the buyer or potential buyer of clothes, as well as on the products themselves, in order to realise long-term company goals, including return on investment (Vinković, 1999). A schematic representation of this philosophy can be seen in Fig. 3.1.

3.2 New product development

The starting point of product development is determined by a company's strategic direction, which is a component of overall company policy. Product development is defined as the design and engineering of products, serviceable for the target consumer, which are marketable, manufacturable, and profitable (Kunz, 1993; May-Plumlee and Little, 1998). The integrated efforts of a multifunctional unit within a business must be employed towards developing such a product and achieving these outcomes.

New product development is one of the most risky and critical strategies in any competitive industry. A new product concept, as defined by M. Crawford and A. Di Benedetto (2003), is 'a statement about anticipated product features (form or technology) that will yield selected benefits relative to other products or problem solutions already available'. According to P. Belliveau *et al*. (2002), a new product is defined as either goods or services which are new to the firm marketing it. R. G. Cooper explains that a product is defined as new if it has been on the market for up to 5 years and includes extensions and major improvements (Cooper, 2001).

According to the literature (Kunz, 1993; May-Plumlee and Little, 1998; Cooper, 2001; Belliveau *et al*., 2002; Crawford and Benedetto, 2003; Choi *et al.*, 2005; Kumar and Phrommathed, 2005), a new product may be classified into several different categories. In simple terms, new products may be:

- *New-to-the-world products.* These are innovations. These new products are the first of their kind and create an entirely new marque. This category represents only 10% of all new products.
- *New category entries.* These are new products or lines which are not classified as new-to-the-world and take the company into a new category. A new category is an imitation of an existing product and provides an entry into new markets. Around 20% of all new products fit into this category (Cooper, 2001).
- *Additions to product lines.* This category contains items which are new to the company but which fit within an existing product line. This is one of the larger new product categories, representing more than 25% of all new products.
- *Product improvements.* These are existing products which have been improved (practically, every product on the market today has been improved) and may be replacements of existing products. They provide enhanced performance or a greater perceived value over the old product and make up 25% of all new products.
- *Repositioning.* These are products targeted toward a new usage or application. The category accounts for around 7% of all new products.
- *Cost reductions.* These are designed to replace existing products at a lower cost.

Companies may implement several actions and strategies to effectively build and sustain competitiveness in the global textile and clothing industry. One strategy is to implement a key new product development function, as well as characterising the role of design in new product development.

3.2.1 Key new product development functions

Developing new products is a complex process. It consists of interdisciplinary activity requiring contributions from most areas of the company (Ulrich and Eppinger, 2004; Choi *et al.*, 2005):

- Marketing is relevant to all stages of the development process of a new product, from planning, through screening and testing, to the launch.
- The design function also plays a pivotal role in defining a physical form of the product which will satisfy customers' needs. Design function includes mechanical, electrical, software and industrial design, aesthetics, ergonomics, and user interfaces (Ulrich and Eppinger, 2004). Industrial design has become a key factor in differentiating products from their competitors through the provision of a coherent identity or higher levels of perceived

value. Engineering design plays a critical role in the development of products in the manufacturing industry. It solves technical problems by the most efficient use of available technologies and by integrating product development with the requirements of effective production.
- Manufacturing is responsible for the creation and operation of systems for new products. Manufacturing capability may be a technical success factor and relates to the internal or external capacity of a company to manufacture higher quality products to meet customer demands (Crawford and Benedetto, 2003; Choi *et al*., 2005).
- Finance is also a key function in the success of new product development.

3.2.2 The role of design in new product development

The role of design varies within the development process of a new product. The evolution of the role of design can be seen in Perks *et al*. (2005), Bailetti and Litva (1995), McDermott (1992) and Menon and Veradarajan (1992) as follows:

- *Nineteenth century:* Design as business oriented. During the 1800s design was integral within broader business and manufacturing techniques.
- *1920s–1950s:* Design as a specialised form. During the 1920s, design grew in importance and was driven by customer affluence and the demand for stylish, aesthetic products.
- *1960s–1970s:* Design as profession. After the Second World War, design became a profession and was viewed as a vital part of economic reconstruction. This was reflected in the development of professional associations such as the British Council for Industrial Design and the Japanese Industrial Designers Association.
- *1980s:* Design as brand. During the 'Designer Decade' of the eighties, design was widely promoted by the media and business worlds. Brands were frequently associated with design and designer labels.
- *1990s:* Design as a sub-process of new product development. Design was perceived as an expensive activity and was brought back in-house instead of using large multidisciplinary design consultancies. Design was no longer perceived as a separate, self-contained process. Research efforts focused on defining and specifying those distinct activities and skills associated with design which was conceptualised as one of many separated functions within the whole innovation process.
- *Early 2000:* Design as product development process leader. Harsh competition has led to an increased emphasis on creativity and innovation as a crucial dimension in recent business strategy. As a result, it has been suggested that designers are now undertaking a leadership role in the product development process.

H. Perks *et al*. offer a taxonomy characterising three roles played by design in the development process of new products. In the first role, design is explored as a functional specialism. The second role develops design as part of a multifunctional team, and the third presents it as a process leader (Perks *et al*., 2005).

Product design is increasingly recognised as an important source of sustainable competitive advantage. C. H. Noble and M. Kumar (2010) have proposed a framework for the creation of design value in consumer products. Taking environmental effects into consideration, this research model (Fig. 3.2) outlines the progression from initial product design goals through the use of so-called design levers and environmental influences (global, local culture), to the developed product and finally, to behavioural and psychological consumer responses. Their study had two major goals:

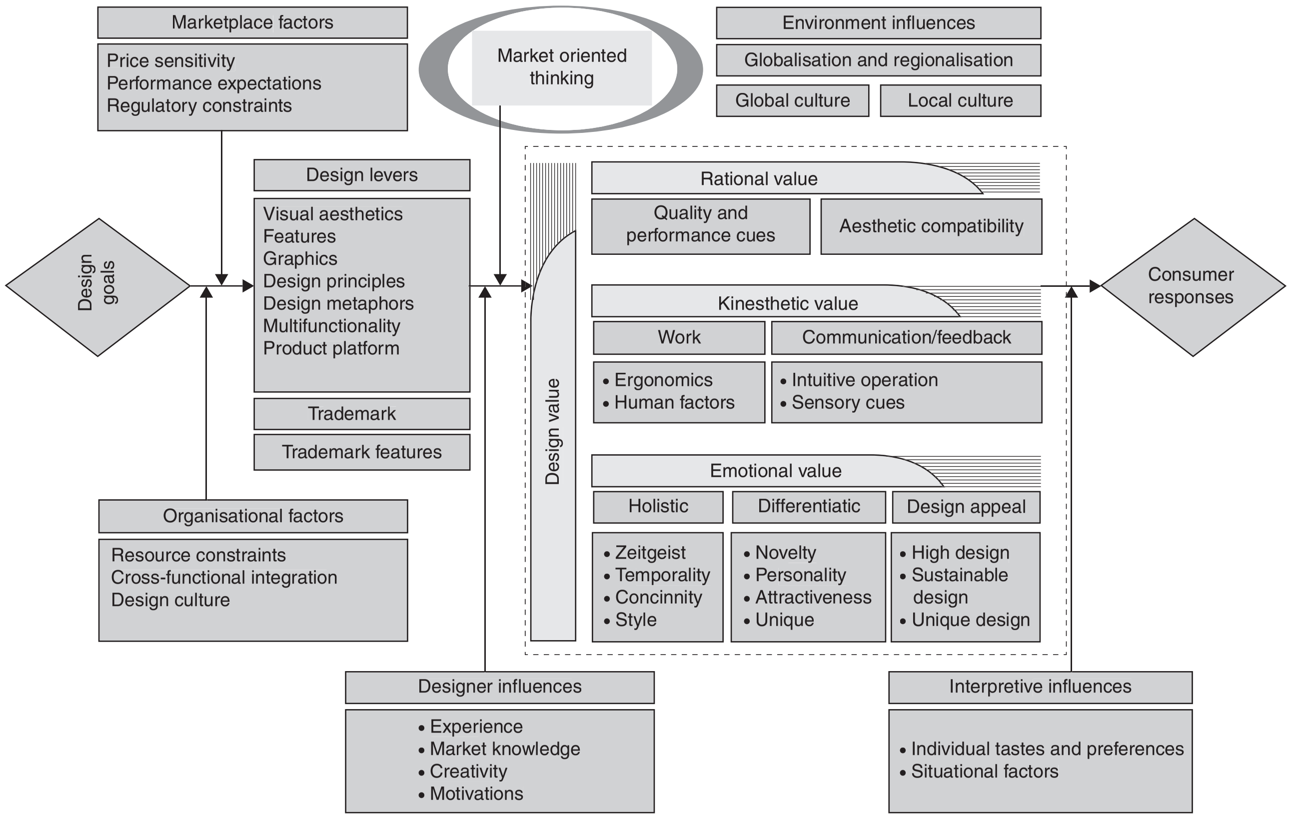
- To identify the key dimensions of design and to develop an enriched language for its understanding and study.
- To integrate aspects of design within a broader model linking initial design goals to the eventual psychological and behavioural responses from consumers.

This framework highlights important elements which go well beyond the usual issues of form and function. The resultant model reflects specific marketplace and organisational constraints which may help or impede the conversion of designer goals into design levers.

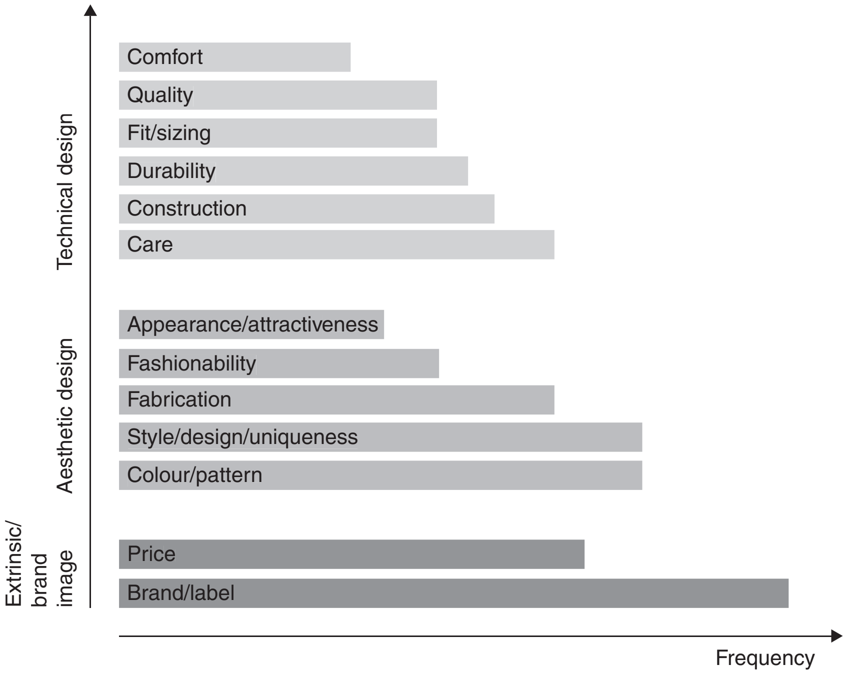
Design has become an important tool in the development of dominant brands with lasting advantages. From the viewpoint of the consumer, a successful brand often offers a guarantee of quality and value, which in turn encourages consumer loyalty. At the international level, successful brands must appeal to consumers from a wide range of cultural, religious, language, and ethnic backgrounds.

3.2.3 Criteria for evaluating garments

Market research provides a means of understanding consumer purchasing decisions and anticipating consumer behaviour. During the product development process, it focuses on identifying opportunities for product innovation and on understanding the evaluation criteria used by consumers in making a purchase decision. T. May-Plumlee and T. J. Little (2006), have integrated consumer purchasing decisions within a model of proactive product development which integrates consumer requirements. They indicate which criteria are relevant for the wearers of clothing. Their ranked and categorised list of so-called 'universal' clothing evaluative criteria is presented in Fig. 3.3 (May-Plumlee and Little, 2006).



3.2 Creation of design value in new consumer products (adapted concerning to Noble and Kumar, 2010).

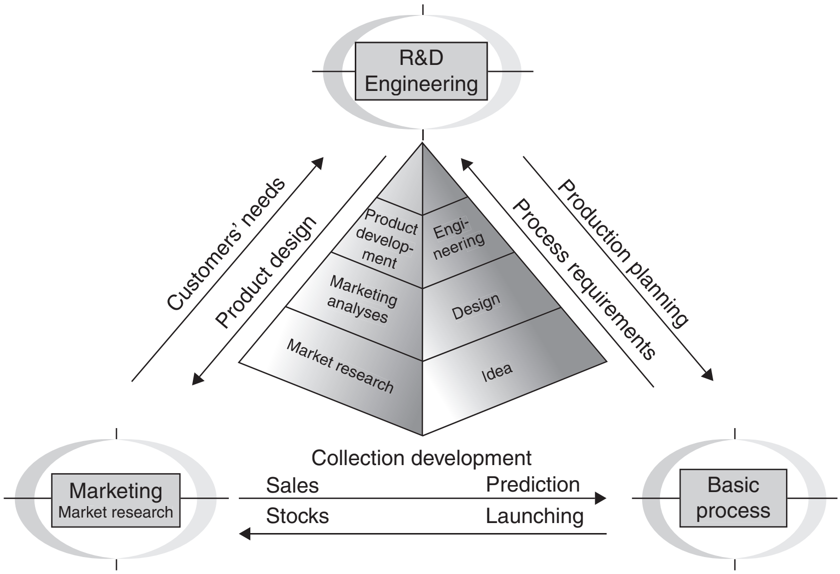


3.3 Ranked and categorised universal evaluative criteria.

To develop successful products, a clothing company must understand the evaluation criteria used by the consumer in making a purchase decision. Consumer-created products provide information about the clothing development process and are also capable of significantly influencing the manner in which clothing is developed. They require development based on individual components and features rather than as a complete style. The proliferation of fashion products in recent decades has given greater importance to the multidimensional role of fashion. It plays a complex role for the consumer, revolving around the dynamics of status expression, identity and socio-cultural milieu.

3.3 Garment collection development

A collection is a range of garment styles (models) designed with respect to current fashion trends and economic realities. Special attention should be paid to collection development when dealing with market requirements and strategic direction. Collection development is a complex process of planning, predicting, designing, and manufacturing new products and/or servicing them within the market. It should be approached on two levels – engineering and business, or economic. The engineering approach includes realising the idea, designing the product, and its detailed technology. The business approach includes



3.4 Integration of engineering and business levels in product development.

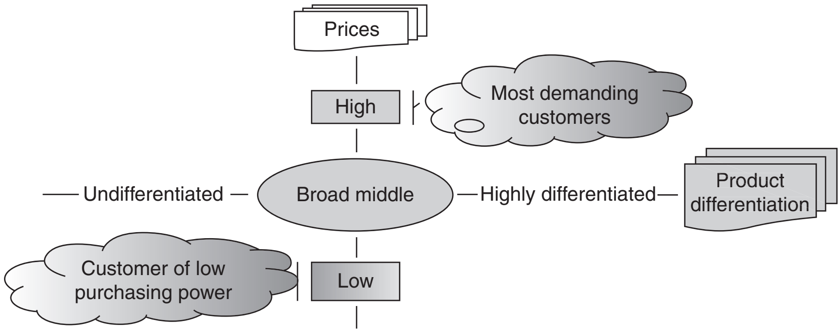
market research and marketing analyses (Fig. 3.4). Research, development and engineering should be directed towards innovative processes in the manufacture and design of new products. All the functions should be harmonised, with each area contributing to a high-quality and successful product. The engineering approach must be based on gradual and planned development of a pre-planned concept and should lead to technical development through careful management and control. Technical development includes the making of patterns and production of the necessary technical documentation.

3.4 Developing the concept for a new collection

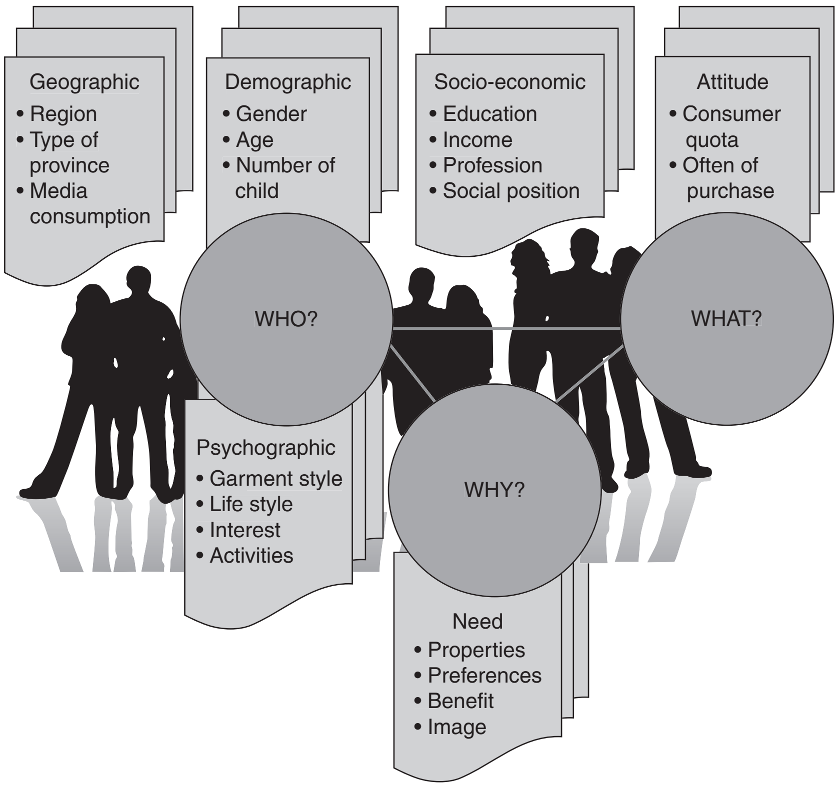
The concept of a collection is based on analysis of the market and the relationships within it, or on the knowledge of a selected segment of customers. It includes the following (Schroven, 1996):

- market and customer segmentation,
- precise definition of target group,
- competition analysis,
- the concept of sales.

Market and customer segmentation is an important factor in producing a collection, there being no average customer and no two people who are exactly alike. In principle, the following segments are available, Fig. 3.5 (Leitl, 1997; Pevec, 1998).



3.5 Segmentation of customers within the garment sector.



3.6 A review of sources for market segmentation.

It is necessary to know which type of approach is most effective for a particular target group and to identify the needs, wishes, and expectations of a particular customer segment in order to match products and communication with these factors. The result is higher customer satisfaction, as well as the identification of strategic opportunities. Figure 3.6 shows the sources of market and customer segmentation. In order to segment a market, it is necessary to make precise definitions of target groups from the points of view of the following groups (Schroven, 1996):

- age,
- income,
- job and social position,
- garment style and other peculiarities (non-standard sizes, sports garments, intelligent clothing).

Competition analysis should be conducted based on the categories described above. This includes:

- identifying possible competition,
- analysing competitors' collections,
- analysing competitors' prices,
- evaluating the company's own collection,
- positioning the company's own collection amongst its competition.

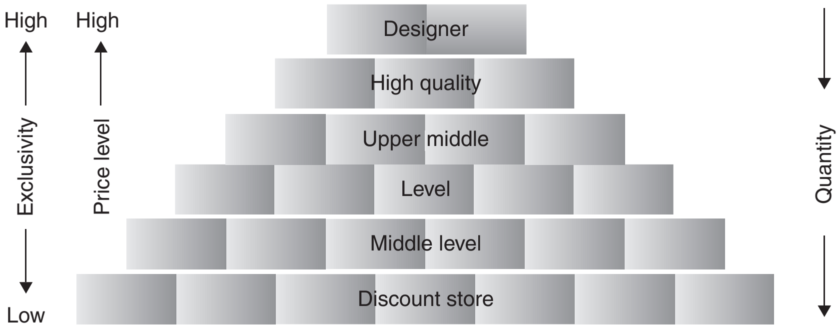
The sales concept should also be clearly defined and special attention paid to the following:

- peculiarities of the philosophy and rules within fashion markets when compared with conventional selling/buying approaches,
- collection with or without a company's own trademark,
- making a broad sketch of the collection,
- determining a sales and procurement schedule,
- selecting sales techniques (specialised stores, subsidiaries, catalogue sales, e-sales),
- selecting sales staff and/or sales representatives,
- determining the size and scope of a collection.

3.4.1 Quality targets for a collection

The quality level defines the rank of the product within the total range of offers in the market. It is an important factor determining the market sector at which a collection will be aimed. Quality levels depend upon:

- fabric quality,
- style and fit,
- fashion content,
- precision of assembly,
- range of sizes and number of pieces,
- workmanship in all components.



3.7 Quality level.

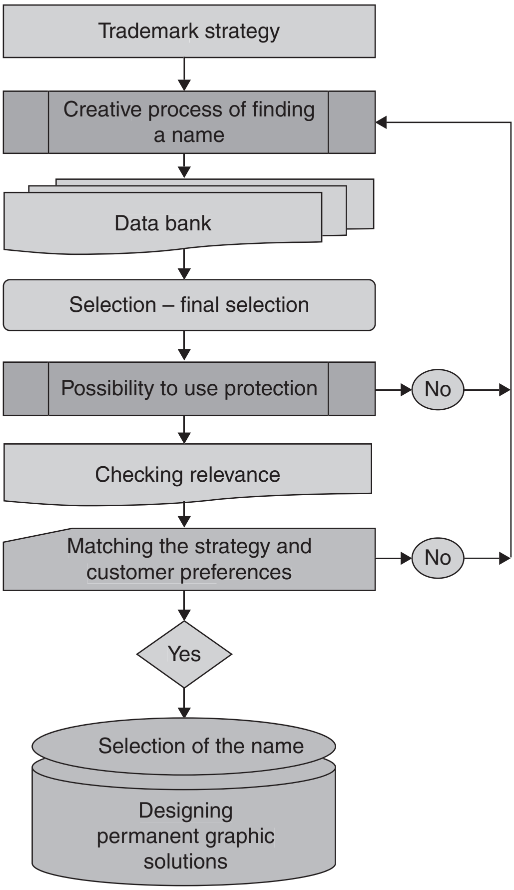
The various quality levels may be distinguished as follows (Fig. 3.7) (Eberle *et al.*, 2002):

- *The discount level*. This incorporates large quantities of limited styles. Fabric quality and workmanship are geared to low price levels, whilst the style and fit are of comparatively lower importance.
- *The middle level*. This has a fixed price, a wide size range and a limited range of styles.
- *The upper middle level*. This uses good quality fabrics and provides an optimum fit. This level of quality follows the latest fashions in style and colour.
- *The high quality level*. This is characterised by very high levels of workmanship, exclusive designs and detailing, a limited size range, small series production and is fashionable.
- *Designer quality*. The characteristics include unique designer labels, small numbers of each style, the most exclusive and/or luxurious fabrics, fashion leader status and avant-garde designs.

3.4.2 Trademarks and their role

Apart from high quality, a necessary precondition for successful competition within the garment market is an acceptable trademark. This may be a name, an expression, a symbol, form, or combination of these. Its purpose is to make the products or services of a particular producer or group of producers recognisable, and to differentiate its products and services from those of its competitors (Kotler, 1996).

Trademarks identify the origin of a product. They protect customers from fake goods and manufacturer from competition (Kunz, 1993). The key in establishing a successful trademark is to combine effective market segmentation with understanding of the trademark's identity on the part



3.8 The process of defining a trademark.

of customers. The process of defining a trademark should be based on an appropriate trademark strategy. A schematic representation of the process for defining a trademark can be seen in Fig. 3.8 (Pevec, 1998).

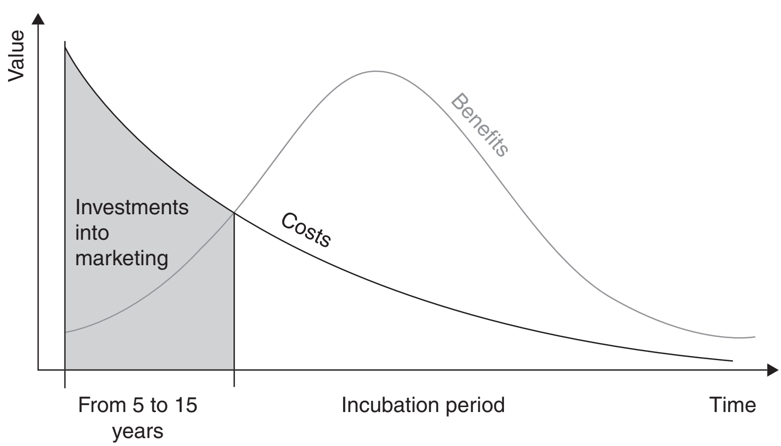
There are four known strategies in naming trademarks for the purpose of definition. These are (Kotler, 1996; Pevec, 1998):

- *Individual name for a particular product*. The company does not therefore risk its reputation on the acceptance of a single market product. If the product or collection fails or proves to be of poor quality, it will have no serious consequence for the manufacturer's reputation.
- *Common company name for all the products*. This offers the obvious advantage of reducing development costs.
- *Separate common names for all the products*. Different names are given to individual collections and denote different concepts.

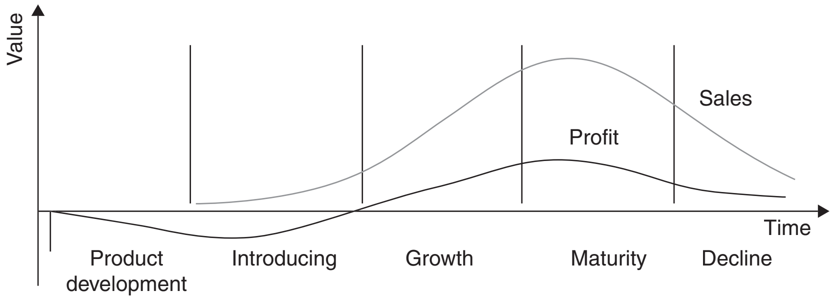
- *Protected company trademark*. The names of individual trademarks contain the protected trademark of the company.

Names, symbols, protected brands and trademarks are of great importance for business success and their selection carries considerable responsibility. The term 'trademark' is often replaced by 'market brand'. This is not a logo or complete image but rather a conglomerate of impressions, tests and ideas experienced by the user in making a connection with the trademark. It has been suggested that trademarks should be subject to continuous development and should follow the expectations of the targeted customer if they are to become a logical part of an integrated system of market communication. Experience has shown that new trademarks need a period between 5 and 15 years for new market incubation. The duration depends on the amount of money invested in a marketing campaign and on the competition, the level of market development, the geographical region and the cultural milieu of customers. The lifetime of a trademark, considered in terms of costs and benefits, may be seen in Fig. 3.9 (Pevec, 1998).

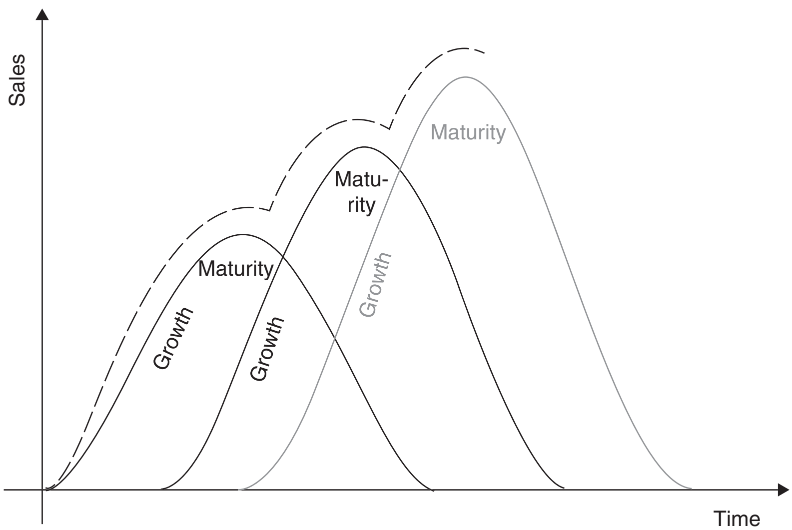
As each trademark is associated with at least one category of products or services which have their own rules, it is necessary to be completely familiar with the categories. Trademarks are placed within a particular market segment and necessitate careful matching. The life-cycle of a product, from its introduction, through growth and maturity to abandonment is considered in terms of sales and profit as shown in Fig. 3.10. Trademarks and brands also offer a clearly defined line between products with precisely expressed details which contribute to the realisation of a particular lifestyle, and products which do not.



3.9 Lifetime of a trademark.



3.10 Product life-cycle from introduction to the market, to abandonment.



3.11 Product life-cycle.

As a product's life-cycle is limited and depends on factors such as the level of investment in the marketing campaign, the condition of the competition, market development, geographical area, culture, clothing-style and life-style, it is necessary to be particularly attentive to product development. The development of a new product should be started during the growth phase of an existing product, so that its growth will coincide with the maturity of its predecessor, Fig. 3.11 (Kornhauser, 2002). If a new product is to succeed, it must offer value for the customer. This value can be functional or emotional–prestigious, or a combination of both (Semolič, 1998). The functional value describes the practical performance. The emotional–prestige value consists of all the other attributes which make the product attractive to a particular segment of customers or users.

3.5 Collection development management and control

The development management and control of a collection includes general collection planning and scheduling, as well as the necessary coordination. Collection planning within a company involves the following (Schroven, 1996):

- arrangement of the collection into product groups,
- decisions regarding outsourcing or in-house manufacture of the collection,
- determination of quality segments,
- determination of the number of pattern and colour quality classes,
- determining the number of price groups according to the needs of the market.

A comprehensive study of the market and the previous season's analyses, as well as knowledge of the competition, is used to build a matrix of predictions for the collection. This requires particular attention to the number of models planned by the manufacturing and pricing groups. To provide the necessary value for the customer/user, the product must meet their required functions. An example of a prediction matrix for blouse models is shown in Table 3.1, whilst Table 3.2 offers a matrix for the whole collection.

Table 3.1 A matrix of collection prediction for the models of blouses

Collection	Number of items predicted	Models				Total number of models
		1st price group	2nd price group	3rd price group	4th price group	
Tara	3.400	5	6	4	3	18
Nella	2.500	3	2	3	4	12
Total	5.900	8	8	7	7	30

Table 3.2 Matrix of collection prediction

Collection	Number of items predicted	Models				Total number of models
		Jackets	Skirts	Blouses	Trousers	
Tara	22.300	8	15	18	17	58
Nella	12.500	6	12	12	14	44
Total	34.800	14	27	30	31	102

3.5.1 Collection scheduling

The scheduling of a collection and the planning of its development consists of (Schroven, 1996) the following:

(a) determination of general terms and dates, links with particular trade exhibition presentations, such as Premiere Vision, Interstoff, Igedo, etc.,
(b) determination of date for submission of the collection,
(c) weekly schedule of collection development e.g. for:
  - ordering fabric and accessory samples,
  - finalising sketches,
  - procuring fabric samples,
  - manufacturing cutting patterns,
  - final manufacture of prototypes and models,
  - confirmation of collection,
  - starting assembly-line production.

3.5.2 Collection development coordination

Coordination of the garment collection development involves:

(a) coordinating and creating time schedules,
(b) planning and scheduling weekly production capacities,
(c) monitoring and fulfilling scheduled items, such as:
  - coordinating the manufacture of cutting patterns and the procurement of fabric samples
  - planning steps to be taken in case of falling behind the schedule
  - booking additional or supplementary production capacities
  - monitoring precision in meeting the schedule
(d) issuing weekly reports on development of the collection to company management,
(e) producing statistics (systematically collected numerical data) on collection development costs,
(f) checking that formal quality requirements are fulfilled, for example, sketch information and quality guidelines.

3.6 Design and manufacturing requirements for a collection

The technical development of a collection has its starting point in design, which plays an important role in development and management. It includes design requirements, manufacture of cutting patterns, and work preparation

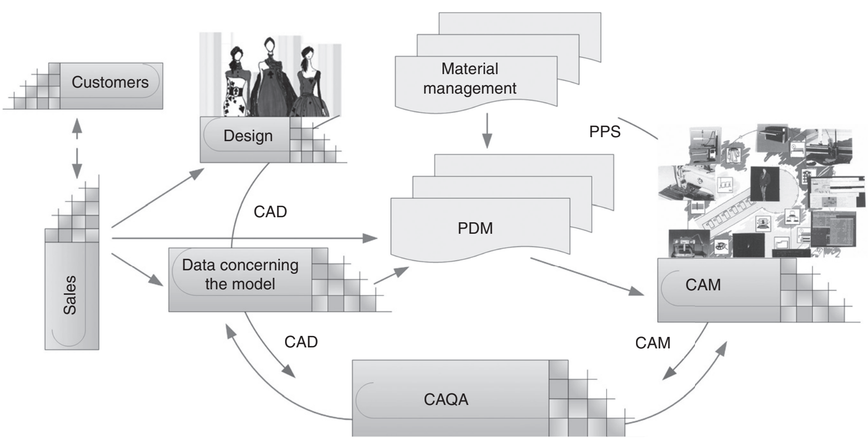
(Schroven, 1996). In designing a product, the functional and aesthetic elements must be considered as well as the available technology, the target market and the optimisation of product costs with the objective of increasing sales and profits. The process of producing a collection consists of a number of phases and steps. These include:

- defining the basic elements, such as collection size, schedule and basic cuts,
- creating the collection, and transferring the data from the models to a computer where simulations are made using different colours and patterns,
- designing model cutting patterns,
- making block patterns,
- selecting equipment for use during manufacture,
- establishing the exact time of manufacturing.

The efficiency of collection technical development depends on many factors, such as the quality of the idea, manufacturing quality and the detailed engineering. An important role is played by contemporary computer-aided systems: computed-aided design (CAD), computer-aided manufacture (CAM), computer-aided quality assurance (CAQA), product data management systems (PDM) and product planning and scheduling (PPS), all of which increase flexibility in the technical development of a collection, Fig. 3.12.

3.6.1 Design requirements

Design requirements during the product development process are influenced by the garment design. This may be defined as a unique combination



3.12 Computer-aided collection technical development.

of variables (silhouette, construction, fabric colour, structure, and texture) within a given class of product or style which distinguish it from other items in the same class (Sproles, 1979; MacGillivray, 2003). Product development should be organised systematically and with continuity. The work programme must be defined in detail and include all the information directly or indirectly involved in realising the product or collection. The following tasks are of particular significance:

- basic definition of any design problem,
- problem specification,
- design concept (the general character and particular style, and guidelines for the themes), having attention to all components including: clothing function, structural and functional complexities of the garments, types and structures of materials and the manufacturing technology used,
- basic determination of fabric concepts: trend themes, fabric qualities, basic and fashion colours,
- stylistic details[1]: the characteristics of these details may determine whether or not a style is considered acceptable by customers.

Design requirements involve:

(a) assessing and preparing adequate forms (manually or by a PDM system) for:
  - model sketch
  - model description
  - list of material
  - quality guidelines

(b) preparing precise data for cutting,
(c) timely ordering of fabric samples and accessories in accordance with the predetermined schedule,
(d) monitoring procurement schedule and informing the coordinator,
(e) employing design systems,
(f) working with silhouettes and lists when performing operations.

Essential conditions for the successful technological realisation of product development and the quality of collections associated with it necessitate precise data regarding the following:

- technical sketches made for the models of garment pieces,
- production instructions for processing,
- a predetermined quality of manufacture,
- meeting production dates.

---

[1] **Stylistic details** – the term may be used to refer to elements of clothing such as lapels, necklines, pockets, belts, buttons, and other ornamentation, such as frills.

3.6.2 Pattern construction

Preliminary design sketches are made and assembled using selected materials and indications of fashion themes to create a storyboard. These ideas are discussed at a collection appraisal meeting in which the scope, balance and image of the collection is decided. Samples of each chosen style are constructed as garment prototypes. Cutting pattern construction connects design to production by producing patterns for all the components, such as cloth, lining and fusible interlining. This is a highly skilled technique which calls for technical ability, sensitivity to the interpretation of design and a practical understanding of the process technology. It includes the following activities:

- making a modular system of silhouettes and their matching design prior to the season,
- designing adequate garment cuts and shapes by following the silhouettes,
- making a model description,
- preparing a list of materials,
- preparing a quality guideline,
- working from a list of necessary technological operations and developing new operations or processes where necessary.

3.6.3 Work planning

Important actions during work planning include:

- quick calculations or evaluations, based on the sketches,
- producing a list of manufacturing operations,
- producing a list of seams,
- real-time calculations for prototypes (material and work requirements),
- checking the list of material, based on the prototypes and calculating the materials used for assembly-line or mass production,
- timely preparations for assembly-line production.

Properly prepared collection development also optimises production in the following areas:

- material disposition,
- quality,
- realisation of the planning schedule,
- defining consumption of material.

Optimising material depends on a number of factors, including:

- optimising block patterns and slopers, where more flexible rules are applied (depending upon the model made and the quality level required)

and making changes in construction provided these contribute to a lower consumption of material and do not affect the appearance of the model,
- proper determination of the necessary material, including all losses during cutting,
- timely data acquisition regarding minimum fabric quality properties, damage, deviations in width, colours or shades,
- planning fabric cutting, bearing in mind permitted allowances and optimising the cutting process.

Based on the quantities required for one item, data from the list of materials are used to calculate the total requirements.

3.7 Design aspects of functional protective clothing: a case study

Over the past few decades, extensive work has been conducted by a number of institutes with the aim of developing efficient protective clothing for industrial workers and the armed forces. The primary requirement for both civil and defence applications is the provision of protection from various hazards and climatic conditions. The increasing need to provide protection for human life against potentially harmful chemicals, military chemical and biological agents, or during situations of natural catastrophe and/or urban terrorism, have brought about a change of approach in designing and evaluating the individual components of a clothing system.

A clothing system is designed by keeping in mind the requirements and expectations of the end-users and must be based on two critical questions:

- What is (for example) the chemical, biological, or radiological challenge?
- What is the work scenario to which it is applied?

Several questions must be answered in relation to the conditions of use and the work environment in order to design the appropriate development methodology and technology for protective clothing and/or clothing systems. These must meet the requirements of the Personal Protective Equipment Directive (Directive 89/686/EEC) and the European and International standards (protection against dangerous substances and infective agents as follows: EN 340:2003, EN 14126: 2003, ISO 6529:2001; ISO 13994:2005, ISO 6530:2005, EN 14325:2004, ISO 22608:2004; for protection against physical injury: EN ISO 13997:1999, EN ISO 13998:2003, EN 530:1994. For protection against thermal hazards: EN IEC 61482–1–2:2007. For protection against heat and/or fire: ISO 14116:2008, EN ISO 11612:2009. For protection against radioactive hazards: ISO EN 1073–1:1998, Hyams *et al*., 2002. For protection against cold and rain: EN 342:2004, EN 343:2003, etc.).

Protection from chemicals is achieved by blocking penetration and permeation through the fabric (ISO 6529:2001; ISO 13994:2005; ISO 6530:2005; EN 14325:2004; ISO 22608:2004; Gopalakrishnam, 2011). Although this is an effective method, total blockage of penetration and permeation also affects transport of the heat and moisture generated by the wearer and may result in heat stress. This illustrates the complexity of designing protective clothing, both from the point of view of protection/comfort and of functionality.

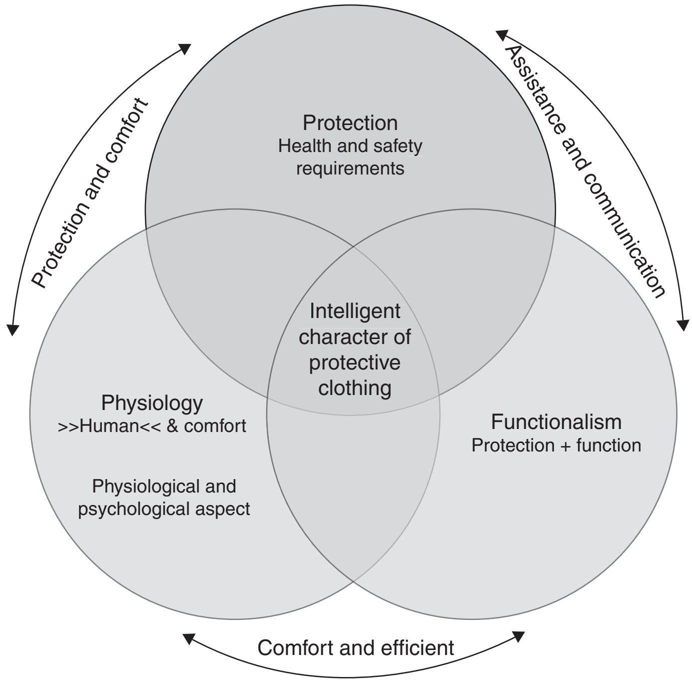
3.7.1 Design requirements for protective clothing

Designing protective clothing as an integral part of personal protective equipment (PPE) is an extremely complex task. Protective clothing must enable the wearer to perform risk-related activities whilst providing the highest possible level of protection. It must be designed and manufactured so as to facilitate the user's movements whilst remaining in position during the period of use, bearing in mind ambient factors and the movements and postures required of the user (Directive 89/686/EEC, EN 340:2003). All appropriate means, such as adequate adjustment and attachment systems and the provision of an adequate size range, must be employed to optimise PPE to user morphology.

Contemporary engineering approaches in the area of protective clothing development offer the opportunity to incorporate so-called intelligent components. Radical innovations in communication and information technology have contributed to changes in the design and development of protective clothing and are used to enhance their functionality by monitoring and evaluating specific hazards encountered by the user. Functional protective clothing with intelligent characteristics is the subject of interdisciplinary research. It necessitates the integration of protection research, material and biological science, clothing engineering, and comfort and functionality, whilst taking into account environmental concerns and communication as illustrated in Fig. 3.13.

3.7.2 Engineering requirements in designing protective clothing

The successful development of personal protection systems and functional protective clothing is only possible in the content of a multidisciplinary research team. The development process for functional protective clothing generally follows that of any new product development. According to Directive 89/686/EEC and the relevant standards, protective clothing must provide adequate technical functionality with intelligent characteristics, as well as the necessary level of comfort and protection against all risks encountered.



3.13 Multidisciplinary approach to functional protective clothing.

Comfort includes physiological, psychological, mechanical and ergonomic aspects. Attention must be focused on the understanding of ergonomic issues, heat stress implications and the relationship between the task and the clothing used. The degree of comfort during wear is defined by the thermo-physiological properties (EN 31092:1993; ISO 11092:1993) of the built-in fabrics and fabric layers, as well as by the specific degree of mechanical and ergonomic comfort. These last two factors depend upon the mechanical parameters of the fabric used, adequate design, and optimal garment construction (ISO 8559:1989; Geršak, 2001; EN 13921:2007; Geršak and Marčič, 2008). Improved fit and comfort are necessary to help in ensuring appropriate use at all times. The clothing must be ergonomically designed in accordance with the dynamic anthropometric conditions of use, whilst comfort and a high degree of freedom of movement are necessary. The clothing should be designed to accommodate all possible conditions of usage, for example, carrying tools, breathing devices, sensor and actuator systems, etc.

Meeting these requirements during the development of personal protection systems should result in optimal protective clothing. The selected process must be clearly defined. A successful design should include the following steps in order to identify basic requirements of user needs and the development of a product which meets those needs (Geršak and Marčič, 2012):

(a) problem recognition
(b) problem definition
(c) objective set-up:
  - defining the level of protection
  - defining additional functions – intelligent character of protective clothing
(d) development of idea/technical solution:
  - choice and acceptability of materials when developing protective clothing
  - defining a method for assessing chemical and/or biological resistance, decontamination
  - defining the physical and mechanical properties and special requirements of the protective materials
  - defining thermo-physiological requirements for the protective materials
  - defining health, safety and comfort requirements
  - defining the components, such as sensors, actuators and processing unit (data processing) storage, transmission and communication functions which will be integrated into the protective clothing
(e) clothing-selection guidelines, including:
  - design specifications
  - prototype construction
  - design refinement
  - prototype development
(f) evaluation/modification/selection of the prototype
(g) checking the ergonomic features of protective functional clothing:
  - wear test/industrial evaluation
(h) evaluation of the solution and its implementation
(i) certification procedures according to Directive 89/686/EEC.

In order to select appropriate materials and styles for the garments, questions concerning the nature of the protection required (chemical or biological) and the operating scenario must be addressed.

Protective materials must provide primary protective properties, such as puncture resistance, flame retardancy, chemical, biological and nuclear resistance, and any required combination of these properties. In addition to the development of new materials, the focus has shifted to those factors which affect the end-user. A new generation of lightweight chemical and biological protective materials has been produced which is based on selective permeable membrane technology. This permits the cell membrane to control the passage of certain molecules. These novel materials provide protection against highly toxic compounds, including offensive chemical and biological agents (Boeniger, 2002; Ashok Kumar and Senthil Kumar, 2004; Butcher, 2008; Obensdorf, 2009). It is important to note that no single material protects against all chemicals and that no material is totally impermeable. The selection of clothing material which will offer the best protection against a particular chemical must be based on its performance upon contact with the chemical (Gopalakrishnam, 2001; Boeniger, 2002).

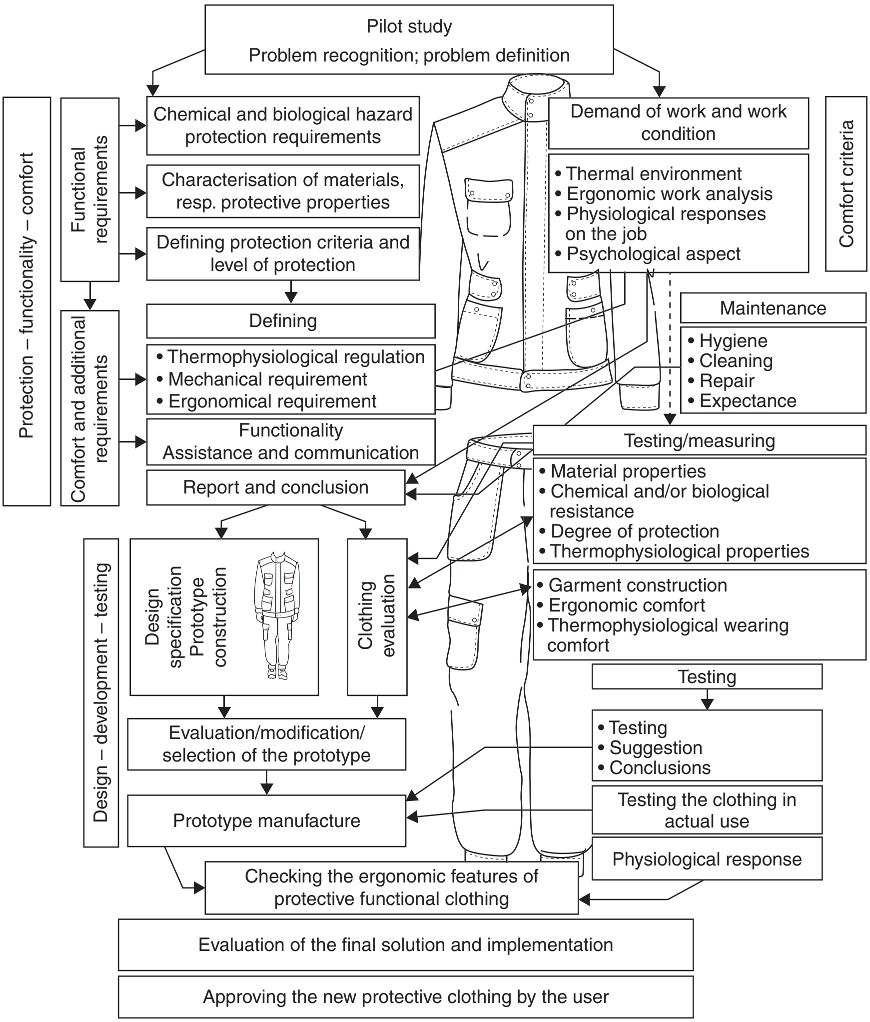
Although the dimensions and weight of technological and electronic components are being reduced, they remain relatively stiff and solid. L. E. Dunne (Dunne *et al.*, 2005) proposes the careful distribution of these solid elements over a body's surface to reduce their perceptibility and discomfort. F. Gemperle *et al.* (1998) addresses this issue by determining optimal shapes for wearable technology.

The complex requirements of material characterisation, design quality and standards in protective clothing must be met to ensure the highest degree of efficiency during use. Following accepted standards is a key factor in designing a garment that will meet the needs of its end-user. The standards deal with:

- requirements concerning the material properties and characteristics of the finished garment in relation to its intended usage and all the conditions which might be encountered in the case of an accident,
- appropriate methods for testing and evaluating the protective properties,
- procedures for marking the individual fields of a protective garment, garment size-systems, CE[2] marking, etc.

The overall strategy for the design, development and implementation of functional protective clothing is shown in Fig. 3.14 (Geršak and Marčič, 2012). This design concept focuses on product development issues through objective characterisation of the materials. These concern verified technical specifications and the development of new methods and techniques for the manufacture of multifunctional protective clothing. They include the integration of health and safety requirements, physiology and comfort, as well as functionality. The intelligent character of functional protective clothing is based on intersectional health and safety requirements, comfort and

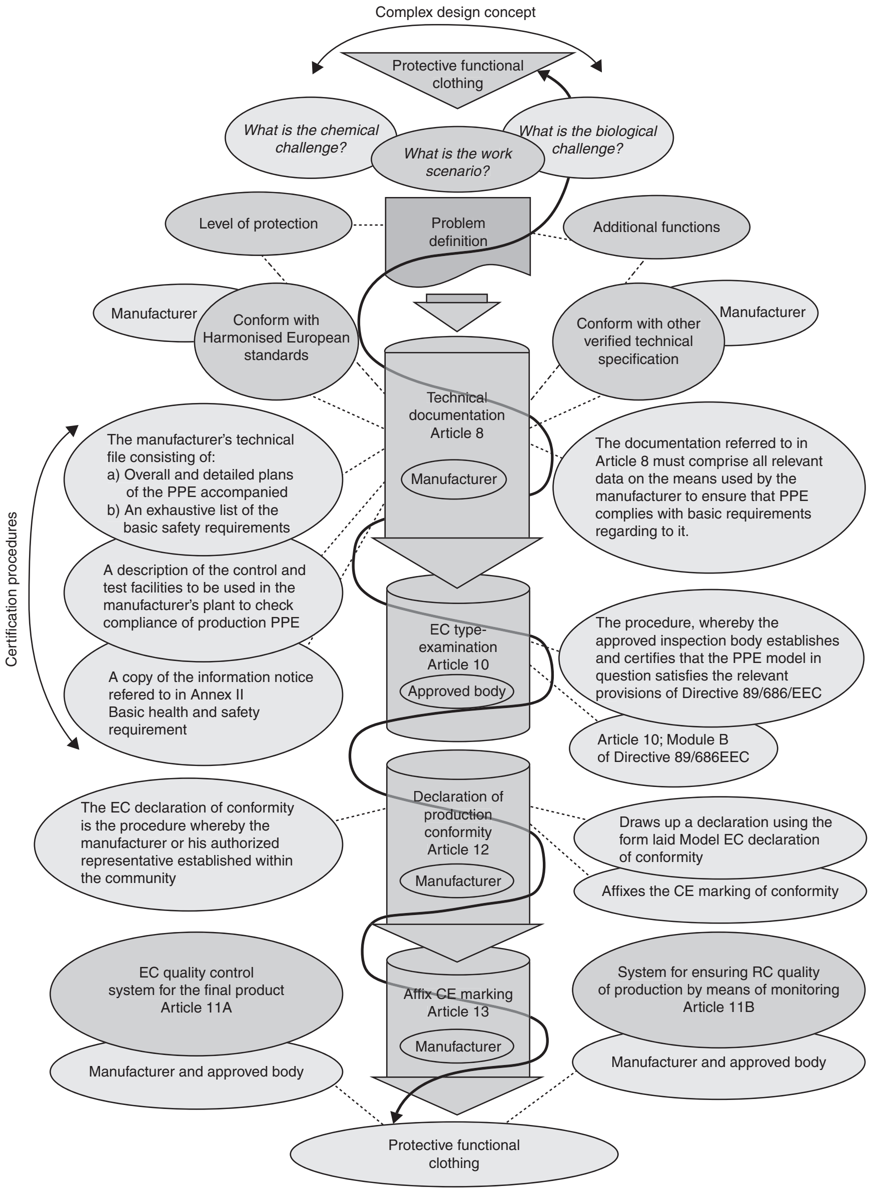
[2] The letters '**CE**' are the abbreviation of French phrase '**C**onformité **E**uropéene' which literally means 'European Conformity'. The term initially used was 'EC Mark' and it was officially replaced by 'CE Marking' in the Directive 93/68/EEC in 1993 (Council Directive 93/68/EEC). The CE Marking on a product is a manufacturer's declaration that the product complies with the essential requirements of the relevant European health, safety and environmental protection legislation.



3.14 Systems approach to the design, development, and implementation of a functional protective clothing system.

functionality, and focuses on the monitoring and evaluation of potential hazards which may be encountered by the user.

The degree of technological integration within a functional protective clothing system depends on the type of intelligent character and its functions. All contemporary protective clothing requires additional equipment for measuring and processing. The complex design concept for the multidisciplinary development of functional protective clothing according to Directive 89/686/EEC, is concerned with the integration of health and



3.15 Flowchart for the complex design concept of functional protective clothing, according to the Directive 89/686/EEC.

safety requirements, physiology, ergonomics, developments in the methodology and technology of protective clothing and the appropriate standards and other verified technical specifications. These are illustrated by the flowchart in Fig. 3.15.

3.8 Fashion trade fairs and garment collections

Quality and efficiency in the presentation of a collection at fashion trade fairs and shows are key factors for the successful development of a collection and for its future position in the market. Participation in trade fairs is an important business decision as it provides a powerful marketing tool and requires a high degree of expertise in preparation and realisation. This involves the following steps (Kirchgeorg *et al*., 2003; CCTC, 2008; Cvitanović, 2009):

- selection of the trade exhibition,
- defining the goals of the presentation,
- planning promotional activities,
- planning the overall costs,
- instruction and preparation of staff,
- evaluating the success of the presentation.

3.8.1 Selecting a trade fair

When selecting the appropriate trade fair for the presentation of a collection, the location, type and purpose of the exhibition should be considered. Decisions must be taken as to whether the product will be presented at a domestic or international fair and if it is to be targeted toward end-users, or on commercial partners where the primary purpose is meeting and discussing business. Selecting the type of fair defines the future business strategy, as does selecting the models and staff to prepare and realise the presentation. An accurate definition of the target group is essential for the presentation. A company must have a clear vision of how it will present its products at a particular exhibition, what its objectives are, which group of customers is to be contacted in order to realise sales, etc. A fashion trade exhibition presentation should be carefully planned and it is important that the staff team is competent to perform all required tasks, both during preparation and presentation and when offering information about the company and/or product to potential customers and business partners.

3.8.2 Defining the goals of trade fair participation

When the trade fair at which the company wishes to present its assortment or collection has been selected, it is necessary to define the presentation goals. These can be:

- collecting necessary information for a particular market,
- monitoring the competition,
- making new business contacts,

- presenting new products,
- nourishing business relationships and contacts,
- completing important business deals,
- promoting the company.

The goals of a trade fair participation may be defined by the so-called SMART model (CCTC, 2008; Cvitanović, 2009):

S(pecific): an efficient presentation is possible only with a clearly defined goal and area of activity.
M(easurable): higher value can be attained only by that which can be precisely measured.
A(chievable): can be performed under reasonable conditions.
R(ealistic): in accordance with real situations.
T(ime-bounded): well-defined time frame based on a schedule.

Special attention should be paid to recording data from the presentation so that it can be evaluated numerically by visitors to the stand, making business contacts, newly-signed deals, etc.

3.8.3 Planning promotional activities

Once a trade fair has been selected and the goals defined, it is necessary to plan the promotional activities. There is a so-called golden rule which states that 'everything that can successfully represent the company should be at the exhibition' (CCTC, 2008). One of the most important elements representing the basis of the company's image and communication, is its Corporate Identity (CI). This encompasses Corporate Design (CD), Corporate Communication (CC) and Corporate Behaviour (CB).

The type of presentation selected will influence the planning of promotional activities. These may be as follows:

- penetrating the market (activating former customers, attentiveness to customers and business relationships),
- product development (the emphasis being on the sales of new collections to existing customers, therefore the presentation should be centred on the collection),
- product development and the opening of new markets (the emphasis being on the creation of new contacts and communications. The stand should be of open design and attractive to potential customers),
- broadening the scope (the presentation should be aimed at both imparting information and advertising the new products and the brand or trademark).

During the fair, particular attention should be paid to the advertising campaign, participation in fashion shows, public relations, and personal contacts, that is, to marketing the event. Effectively designed advertising material such as catalogues, prospectuses, compact discs, price lists, reference lists and business cards is also necessary. Particular attention should be paid to the selection of media and the preparation of an accurate time schedule for advertising. The model AIDAS (**A**(ttention) **I**(nterest), **D**(esire), **A**(ction), **S**(atisfaction)) (Geml and Lauer, 2008) may be used for this purpose.

3.8.4 Planning the overall cost

Cost should be planned on the basis of the presentation goals, the type and aims of the exhibition itself and the model of presentation employed. These factors form a basis on which a plan of the overall presentation costs is made. Investigations have shown that the overall costs of a presentation made at a domestic exhibition may be calculated by taking the price of the basic exhibition space multiplied by a factor of three to five, depending upon size. The multiplier for trade exhibitions abroad is a factor of between four and eight (CCTC, 2008; Cvitanović, 2008).

3.8.5 Preparation of staff for trade fair presentations

Staff preparation for a trade exhibition presentation is important. Even the best arranged stand will not meet the goals if the display is not comprehensive and of high quality. The team in charge of the preparation and organisation of the presentation, should be equipped to answer the following questions:

- What are the goals of the exhibition?
- What are the company's key comparative advantages and where does its strength come from?
- Who are the main competitors?
- What image of the company and its products should be presented to the market?

If they are to be efficient, the team must be aware of their responsibilities and tasks (i.e., who is in charge of the visitors, who is in charge of distributing information material, etc.). It is recommended that staff wear name badges and an identifiable form of dress which contribute to efficiency and to their professional image. Data should be collected throughout the exhibition. This involves reporting on contacts with visitors, monitoring the activities of the competition and making both written and visual (film and photographic) records.

3.8.6 Evaluating the results of trade fairs

In evaluating the success of a presentation, it is necessary to assess competitors' suppliers and offerings (both collections and individual products). Analysis of recordings of suggestions and opinions from visitors can be used in planning future presentations. In order to evaluate and assess whether the expected goals of the presentation were achieved, the exhibition should be tested whilst in progress and upon its completion. Efficiency testing whilst in progress involves the following:

- analysis of visitors' interests in the products as a simple instrument of control,
- analysis of overall number of visits to the stand and degree of interest in individual products,
- collection of visitor data regarding specific information on their companies, reasons for visits, etc.,
- analysis of more complex and individual questions asked by visitors. These should be sorted into those which can be answered orally and those which require written responses.

A costs coefficient per visitor is used to evaluate the success of an exhibition presentation, where the number of the visitors at the stand is compared with the overall costs (Cvitanović, 2009):

$$k_{ob} = \frac{S_{sk}}{N_{ob}}, \qquad [3.1]$$

where:

$$S_{sk} = S_{rp} \cdot f \qquad [3.2]$$

and:

k_{ob}: costs coefficient per visitor,
S_{sk}: overall exhibition presentation costs,
S_{rp}: the cost of the basic stand space,
f: factor,
N_{ob}: number of visitors.

Information on the overall cost per single visitor is obtained in this way. The data is then compared with the direct retail and advertising costs. Although a company's image and position in the market is difficult to quantify, the success of an exhibition presentation is important, both for its image and for the strengthening of its position in the market. Carefully planned participation in national and international trade fairs offers exhibitors the opportunity to present a special package as a unique offer.

Trade exhibitions are the only occasions which offer direct communication with interested partners. They also provide opportunities for the efficient presentation of new products or collections, the distribution of information about a company, the collection of useful information and approaches to new ideas, the exchange of experiences, the establishing of direct contacts, meeting existing customers and becoming acquainted with potential new customers. An overall evaluation may also provide some information about the position of the company in relation to its competitors.

3.9 Conclusions

The clothing industry has undergone considerable change in recent years as globalisation and communication stimulate competition. The market share gained by a product will be dependent upon the quality which determines the price customers are willing to pay for it. A product which sells well and makes a profit reflects a successful development process and presentation. The decisive steps in this process are the development of a consumer- and market-friendly strategy, the identification of consumer needs, the definition of a collection according to quality targets, trademarks, knowledge of successful product development and a correct reading of market conditions.

3.10 References

Anon. (1989), *Textile lexicon* (in Slovenian), Ljubljana, University of Edvarda Kardelj in Ljubljana, Faculty of Science and Technology, Textile technology.

Anon. (2002), *Big dictionary of foreign words* (in Slovenian), editor: M. Tavzes et al., First edition, Ljubljana, Published by Cankarjeva založba.

Ashok Kumar, L. and Senthil Kumar, R. (2004), Protective Textiles, *Asian Textile Journal*, **13** (11), 93–106.

Bailetti, A. and Litva, P. (1995), Integrating Customer Requirements into Product Designs. *Journal of Product Innovation Management*, **12** (1), 3–15.

Belliveau, P., Griffin, A. & Sometmeyer, S. (2002), *The PDMA Toolbook for New Product Development*, New York: Product Development & Management Association.

Boeniger, M. (2002), *Chemical Protective Clothing and the Skin: Practical Consideration, National Institute for Occupational Safety and Health/CDC*, Cincinnati, Ohio, First printing.

Butcher, David R. (2008), Military Targets Material Innovation, IMT Industrial market trends, 1–3.

CCTC (2008), *A guide to a successful presentation at trade fairs* (in Croatian), Zagreb, Croatian Chamber of Trades and Crafts, Second edition.

Choi, W., Powell, N. B. and Cassill, N. L. (2005), New product development and its applications in textiles, *Journal of Textile and Apparel, Technology and Management*, **4** (4), 57–84.

Cooper, R. G. (2001), *Winning at New Products*, 3rd edition, New York: Addison-Wesley.

Council Directive 89/686/EEC – Personal protective equipment, OJ L 399, 0.12.1989, p. 18.

Crawford, M. and Benedetto, A. D. (2003), *New Product Management*, 7th edition, New York: McGraw-Hill.

Cvitanović, V. (2009), *How to prepare a successful trade-exhibition presentation at national and international trade fairs* (in Croatian), Book of Proceedings, Zagreb, Second scientific-professional conference Textile science and economy, University of Zagreb, Faculty of Textile Technology, 73–80.

Dunne, L. Ashdown, S., Smyth, B. (2005), Expanding Garment Functionality through Embedded Electronic technology, *Journal of Textile and Apparel, Technology and Management*, **4** (3), 1–11.

Eberle, H., Hermeling, H., Hornberger, M., Kilgus, R., Menzer, D., Ring, W. (2002), *Clothing Technology, Third English Edition*, Haan-Gruiten, Verlag Europa-Lehrmittel, Nourney, Vollmer GmbH & Co.

EN 340:2003 Protective clothing: General requirements.

EN 342:2004 Protective clothing – Ensembles and garments for protection against cold.

EN 343:2003 Protective clothing – Protection against rain.

EN 530:1994 Abrasion resistance of protective clothing material – Test methods.

EN 1073–1:1998 Protective clothing against particulate radioactive contamination –Ventilated suits.

EN 13921:2007 Personal protective equipment. Ergonomic principles.

EN 14126:2003 Requirements for protection against biological hazards in the highest performance class.

EN 14325:2004 Protective clothing against chemicals. Test methods and performance classification of chemical protective clothing materials, seams, joins and assemblages.

EN 31092:1993 Textiles – Determination of physiological properties – Measurement of thermal and water-vapour resistance under steady-state conditions (sweating guarded-hotplate test).

EN IEC 61482–1–2:2007 Live working – Protective clothing against the thermal hazards of an electric arc – Part 1–2: Test methods – Method 2: Determination of arc protection class of material and clothing by using a constrained and directed arc.

EN ISO 11612:2009 Protective clothing against heat and flame.

EN ISO 13997:1999 Protective clothing. Mechanical properties. Determination of resistance to cutting by sharp objects.

ISO 13998:2003 Protective clothing – Aprons, trousers and vests protecting against cuts and stabs by hand knives.

Geml, R., Lauer, H. (2008), Marketing- und Verkaufslexikon, 4. Auflage, Stuttgart, Schäffer-Poeschel Verlag.

Gemperle, F., Kasabach, C., Stivoric, J., Bauer, M., Martin, R. (1998), *Design for wearability*. Proceeding of the 2nd International Symposium on Wearable Computers, Pittsburg, 116–122.

Geršak, J., Marčič, M. (2012), *The peculiarities of a complex design concept for functional protective clothing*. CBMTS Industry VII, World Congress on CBRN

Threat and Terrorism with the Workshop on the Chemical Weapons Convention Protection against Chemical Weapons and Prevention of Terrorist use of WMD related Materials, Proceedings of the CB Medical Treatment Symposium, Cavtat, Croatian Chamber of Economy, 248–254.

Geršak, J., Pevec, B. (1993), *The strategy of Slovenian clothing industry development – a basis for a successful development of Slovenian clothing manufacturers* (in Slovenian), Tekstilec, **36** (2), 49–55.

Geršak, J. (2001), *Designing a garment system from the point of view of thermophysiological comfort*. Proceedings of the 12th International DAAAM Symposium Intelligent Manufacturing & Automation, Jena University of Applied Sciences, Jena, DAAAM International, 157–158.

Geršak, J., Marčič, M. (2008), Assesment of thermophysiological wear comfort of clothing systems, *Tekstil*, **57** (10), 497–515.

Gopalakrishnam, D., Nithiyakumar, M., Nayak, A. (2011), *Development of chemical protective clothing*, presented by www.fibre2fashion.com [Accessed 15.3.2011].

Hyams, K. C., Murphy, F. M., Wessely, S. (2002), Responding to chemical, biological, or nuclear terrorism: The indirect and long-term health effects may present the greatest challenge, *Journal of Health Politics Policy and Law*, **27** (2), 273–292.

ISO 6529:2001 Protective clothing – Protection against chemicals – Determination of resistance of protective clothing materials to permeation by liquids and gases.

ISO 6530:2005 Protective clothing – Protection against liquid chemicals – Test method for resistance of materials to penetration by liquids.

ISO 8559 ISO 8559:1989 Garment construction and anthropometric surveys – Body dimensions.

ISO 11092:1993 Textiles – Physiological effects – Measurement of thermal and water-vapour resistance under steady-state conditions (sweating guarded-hot-plate test).

ISO 13994:2005 Clothing for protection against liquid chemicals – Determination of the resistance of protective clothing materials to penetration by liquids under pressure.

ISO 14116:2008 Protective clothing – Protection against heat and flame –Limited flame spread materials, material assemblies and clothing.

ISO 22608:2004 Protective clothing against liquid chemicals. Measurement of repellency, retention, and penetration of liquid pesticide formulations through protective clothing materials.

Kirchgeorg, M., Dornscheidt, W. M., Giese, W., Stoeck, N. (2003), *Handbuch Messemanagement: Planung, Durchführung und Kontrolle von Messen*, Kongressen und Events, Wiesbaden, Gabler Verlag.

Kornhauser, A. (2002), *Economic dimensions of knowledge, The importance of knowledge and the role of state in improving international competitiveness of textile and leather companies* (in Slovenian), Book of proceedings, Ljubljana, Slovenian Chamber of Commerce.

Kotler, P. (1996), *Marketing management* – Tržno upravljanje (in Slovenian), Ljubljana, Slovenska knjiga.

Kumar, S., Phrommathed P. (2005), *New Product Development – An Empirical Study of the Effect of Innovation Strategy, Organisation Learning, and Market Conditions*, New York, Springer, 55–57.

Kunz, G. (1993), *Phases of Product Development: Preadoption and Postadoption,* Iowa State University Media Resources Center, Ames, IA.

Leitl, J. (1997), *Profitable Wachs – eine Illusion? Studie für die Branche „Personal Outfit",* Textil 1997, Köln.

MacGillivray, M. S., Hann, M. A. (2003), The Fashion Consumer in the Global Marketplace, *Textile Progress*, **33**, 47 pages.

May-Plumlee, T., Little, T. J. (1998), No-interval coherently phased product development model for apparel, *International Journal of Clothing Science and Technology*, **10** (5), 342–364.

May-Plumlee, T., Little, T. J. (2006), Proactive product development integrating consumer requirements, *International Journal of Clothing Science and Technology*, **18** (1), 53–66.

McDermott, C. (1992), *Design Museum Book of Twentieth Century Design*, London, Carlton Books Ltd.

Menon, A., Veradarajan, P. (1992), A Model of Marketing Knowledge Use within Firms, *Journal of Marketing* **56**, 53–71.

Noble, C. H., Kumar, M. (2010), Exploring the Appeal of Product Design: A Grounded, Value-Based Model of Key Design Elements and Relationships, *Journal of Product Innovation Management*, **27** (5), 640–657.

Obensdorf, S. K. (2009), Improving personal protection through novel materials, (AATCC Olney Medal Award Winner), *AATC Review*, July/August, 44–56, Available from: http://WWW.aatcc.org.

Perks, H., Cooper, R., Jones, C. (2005), Characterizing the Role of Design in New Product Development: An Empirically Derived Taxonomy, *Journal of Product Innovation Management*, **22** (2), 111–127.

Pevec, B., Geršak, J. (1992), *The strategy of Slovenian clothing industry development* (in Slovenian), Book of proceedings, Garment engineering '92, Maribor, University of Maribor, Faculty of mechanical engineering, 1–13.

Pevec, B. (1998), *What are the possibilities of survival and development of Slovenian garment industry?* (in Slovenian), Book of proceedings, Garment engineering '98, Maribor, University of Maribor, Faculty of mechanical engineering, 15–29.

Schroven, L. (1996), *Product development* (in Slovenian), Book of Proceedings, Garment engineering '96, Maribor, University of Maribor, Faculty of mechanical engineering, 33–36.

Simmel, G. (2000), *Selected papers on culture: Philosophy of fashion* (in Slovenian), Ljubljana, S. Humanitatis.

Semolič, B. (1998), *Developing additional value* (in Slovenian), Book of Proceedings, Garment engineering '98, Maribor, Faculty of mechanical engineering, 30–37.

Sproles, G. B. (1979), *Fashion: Consumer Behaviour towards Dress*, Burgess, Minneapolis, MN, USA.

Ulrich, K. T., Eppinger, S. D. (2004), *Product Design and Development,* 3rd edition, New Jersey, Prentice-Hall.

Vinković, M. (1999), *Garment design I* (in Croatian), First Book, Zagreb, Faculty of Textile Technology, University of Zagreb.

4
Planning and organisation of clothing production

DOI: 10.1533/9780857097835.87

Abstract: This chapter first discusses the key terms and roles in clothing production planning and organisation. Clothing-design analysis and activity planning are then explained. The chapter then discusses quality requirements during manufacture, and includes a case study of the quality requirements for a finished article of clothing.

Key words: production planning, organisation, clothing design, list of materials required, manufacture quality requirements.

4.1 Introduction

Clothing production planning is one of the most important prerequisites for the efficient flow of a clothing-manufacturing process with regard to acceptable quality. Its purpose is to investigate in detail, before the manufacture of a new garment, the requirements of the product, its materials of construction and the manufacturing processes required to produce the final product. Planning aims at recognising in advance all factors that influence the manufacturing process in question. The requirements for manufacturing and assembling the product should be defined and studied in detail, the time schedule determined, and appropriate controls established. The transformation of the raw material into the final product must be accomplished quickly, easily, economically and efficiently, and the resulting product must be of acceptable quality and desirable to the end user, the customer.

Production systematics plays an important role, being focused primarily on the organisational integration of manufacturing processes. Production systematics involves all the technical and organisational tasks that occur during product development, so that end-products are market oriented. The role of production planning (following a decision as to 'what' to produce, 'how' to produce it, and with 'what' tools and equipment) is to adapt the manufacturing process to the available means of production, and shape it so as to ensure optimal production regarding time, costs and quality. Effective production management ensures optimal material flow during the manufacturing process, continuity of the process as regards the workforce and workplace, and as short a manufacturing cycle as possible (Geršak *et al.*, 1994), whilst production scheduling ensures those planned activities are carried out within the time required (Eversheim, 1989). The necessary activities have to be planned and allocated, and a chain of responsibility established, in order for this to be achieved.

Clothing-manufacturing processes are labour intensive, involving processes that require a high degree of operator competence. Being able to deal with people also involves understanding cultural issues, bearing in mind the culture of an organisation is the combined effect of the values, beliefs, attitudes, traditions and behaviour of its members (Lewis, 1995).

4.2 Production planning and organisation within a company

Production planning can be represented by those functions and activities that unite and link clothing-pattern construction (design) and manufacturing technology (production), through four closely related organisational units:

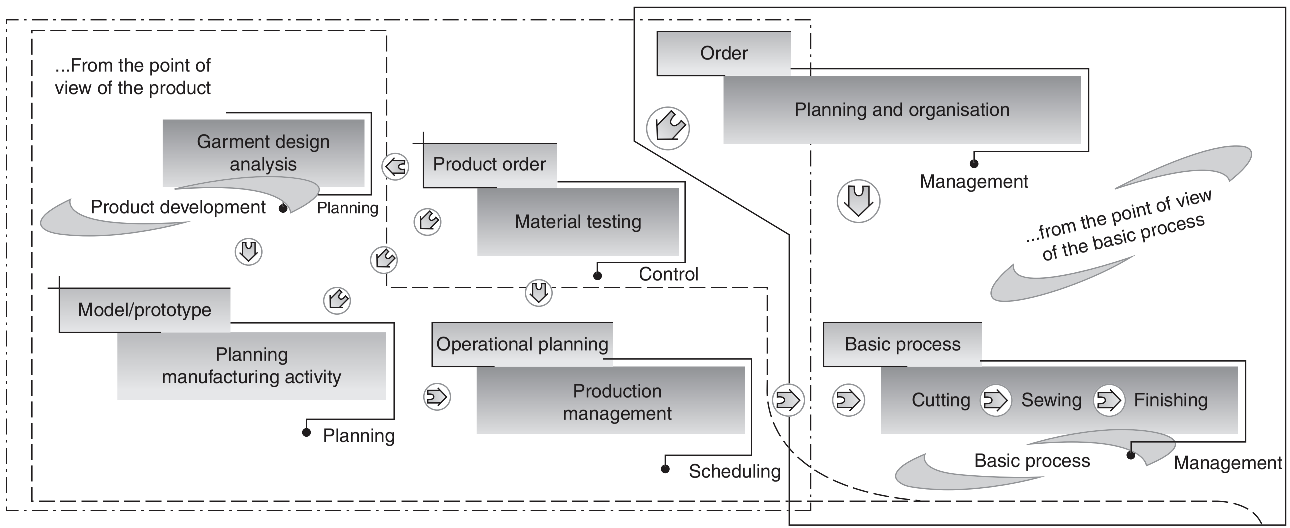
1. Clothing-design analysis, pattern making, and planning production activities;
2. Planning and control of clothing-manufacturing activities;
3. Clothing production management; and
4. Material testing.

Only proper organisation ensures the optimal planning and coordination of the manufacturing process, as a basic process that transforms material inputs into products or services (Geršak, 1993). In this regard, it is also worth mentioning the engineering function during manufacture, for this involves the design, planning and control of manufacturing processes and manufacturing production. A schematic representation of positioning production planning and organisation within the basic process can be seen in Fig. 4.1.

Because of the pressures within this dynamic marketplace, as in any other industry, in order to remain competitive clothing manufacturers need to:

- deliver on time;
- respond quickly;
- deliver to a given price;
- reduce 'work in progress'[1];

[1] **Work in Progress** (WIP) – material that has entered the production process but is not yet a finished product. WIP therefore refers to all materials and partly finished products that are at various stages of the production process. As such, WIP excludes inventory of raw materials at the start of the production cycle and finished products inventory at the end of the production cycle. Also referred to as work in process.



4.1 Positioning production planning and organisation within the basic process.

- reduce excess costs such as overheads;
- improve productivity;
- introduce best practices; and
- achieve accurate and consistent information (Collins and Glendinning, 2004).

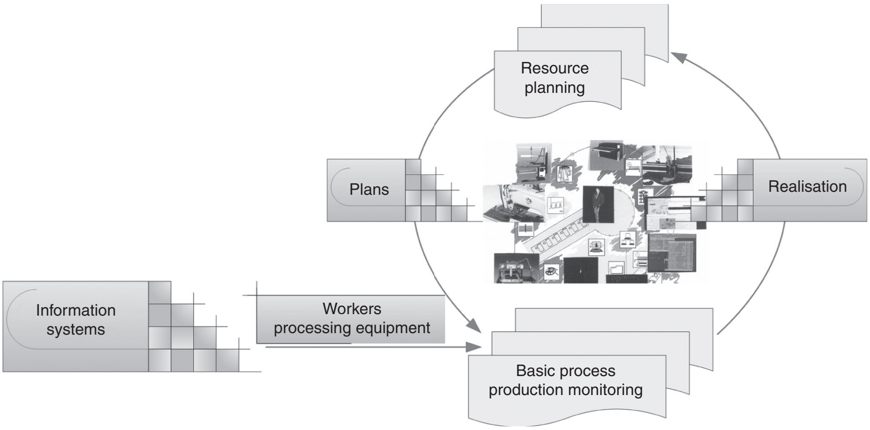
Good production planning and control are fundamental. In order to achieve specified planning and organisational objectives, it is necessary to be fully familiar with the properties and characteristics of the three basic elements present during every clothing-manufacturing process:

1. The raw material being processed – Material;
2. The processing equipment – Machines; and
3. The person executing the process – People.

It is also worth mentioning the so-called geometric principles of clothing design. Knowledge of a fabric's behaviour during its transformation from a two-dimensional plane into a three-dimensional article of clothing, and characteristics of the materials involved, are of prime importance for efficient production. It is, therefore, necessary to be able to identify and understand the natural characteristics and the mechanical and physical properties of fabrics (Kawabata *et al.,* 1990, 1992; Geršak, 2008; Geršak and Zavec Pavlinić, 2000; Zavec Pavlinić and Geršak, 2004).

An important role is played by material testing: investigating and testing the materials to be included in the clothing with regard to the functional and technical requirements imposed upon them. It involves mechanical, physical and chemical tests on the basic and auxiliary materials and their accessories, as well as checking and defining the minimum quality criteria required. Planning and determining processing parameters will ensure a smooth manufacturing process and the required quality level. These parameters are directly related to quality-control requirements, some of which will be discussed in a later chapter dealing with quality requirements for clothing materials. Production planning includes the planning of manufacturing and assembly processes, as well as the process of clothing finishing. These processes and their order of application are precisely determined, so planning also needs to take into account the reliability of the equipment necessary to make the products.

Production planning is an organisational unit in itself. Effective data flow is of the utmost importance (Geršak, 1993; Podlesek and Geršak, 1993; Kleindienst, 2008). The information system gathers the data that a production manager uses in order to know whether a basic process is on target or not. However, this information must be timely, and one of the problems organisations often have is that the data on process performance



4.2 Data flow among different information systems within a company.

is gathered, fed into a mainframe computer, then batch processed and distributed over such large time intervals as to make the information useless for control. This is discussed further in the chapter on production monitoring and control.

An adequate information system that connects production planning and basic process flow is a prerequisite for successful production. The information system should be designed so as to ensure data exchange between the management system and the production process, meaning that it creates a closed cybernetic[2] circle, as can be seen in Fig. 4.2. The data obtained from the basic process, together with the data acquired from the environment, create the essential information for the information system.

4.3 Clothing-design analysis and activity planning

The life cycles of fashion articles are much shorter (a single season, i.e. up to six months) than the life cycles of other products. In addition, the price of fashion clothing is often drastically reduced by the end of the products' life-cycle (the season) as the psychologically perceived value of fashion clothing quickly deteriorates. Therefore, to work successfully within these

[2] **Cybernetic –** from **cybernetics** [from Gr. *kybernétes* steersman] – the scientific study of the way in which information is moved and controlled in machines, the brain and the nervous system; the science exploring communication and control mechanisms in machines and living creatures. It is an interdisciplinary science studying rules in regulatory processes, data transfer and data processing in machines, organisms and societies.

constraints, collection development and clothing-design analysis needs to be extremely well planned, organised and managed, whilst the design and manufacturing functions must be closely associated.

The successful launch of a new product or collection within a demanding fashion market depends not only on being familiar with the market, but also on having a good working knowledge of the technical and technological characteristics of the clothing's production and the specific requirements of fashion marketing. Fashion marketing differs from other marketing areas in that it is strongly influenced by its environment, time pressures (fashion garments lose value quickly and should be distributed as quickly as possible to the places where they are to be sold), as well as by the role of the customer (the decision to purchase is strongly influenced by a customer's personality). It is therefore necessary to ensure proper, professional, and flexible clothing-design analysis and planning, and a preliminary analysis of risk and the resulting impact on time, cost, and performance requirements is also very important during this phase.

Although the psychological value of an article of clothing as a fashion article is more pronounced than the physical properties and benefits of the product (i.e., warmth, comfort, and protection from external influences), it is necessary to study and determine, within the content of the clothing-design analysis, the necessary physical properties of the product. In order to ensure the quality of the manufacturing process and the product itself, it is necessary to determine the quality requirements and standards in advance, as well as the requirements for smooth technological processing, up to the finished product.

Standardisation plays an important role in the above, contributing to cost reduction through simplified manufacturing processes, and instituting order and technical discipline when performing individual processes and operations. Standards dictate the rules, directions or instructions for particular operations, or the expected results. Standards are intended to be used generally, and are aimed at attaining an optimal order within a particular area. They should be based on verified scientific, technical, and empirical results, so as to enable general and optimal implementation. As well as the standards, rules developed from in-plant practice are also used, together with technical regulations. The rules from in-plant practice are those that recommend technical rules or procedures during the development, manufacture, care or usage of equipment, construction or products.

Clothing-design analysis and activity planning is an extremely important aspect of the design and manufacture of new products, and is the basis of any efficient process regarding high-quality clothing manufacture. Clothing-design analysis connects ideas, engineering design, and technology, and is indirectly involved in fashion design and fashion marketing. Clothing-design analysis and activity planning, as one part of production planning, is the area responsible for:

(a) determining the contents of development documents (manually or by using computerised equipment), including:
   - model sketch;
   - model description;
   - list of materials; and
   - quality guidelines;

(b) pattern construction;
(c) pattern grading;
(d) marker planning and making;
(e) determining fabric consumption; and
(f) defining detailed cutting-data.

Initially, the preparation of detailed plans required to support the clothing-manufacturing process predominates, including the preparation of all documentation necessary to support the production process.

4.4 Key documentation

The precise data to be used as the basis for defining product and manufacturing processes should be known, in order to achieve an efficient and high-quality production process (Eversheim, 1989). The definitions of products and processes are included within the basic development or the so-called technical documents. Identification and initial preparation of all documents required to support the system as a manufacturing process are very important during this phase.

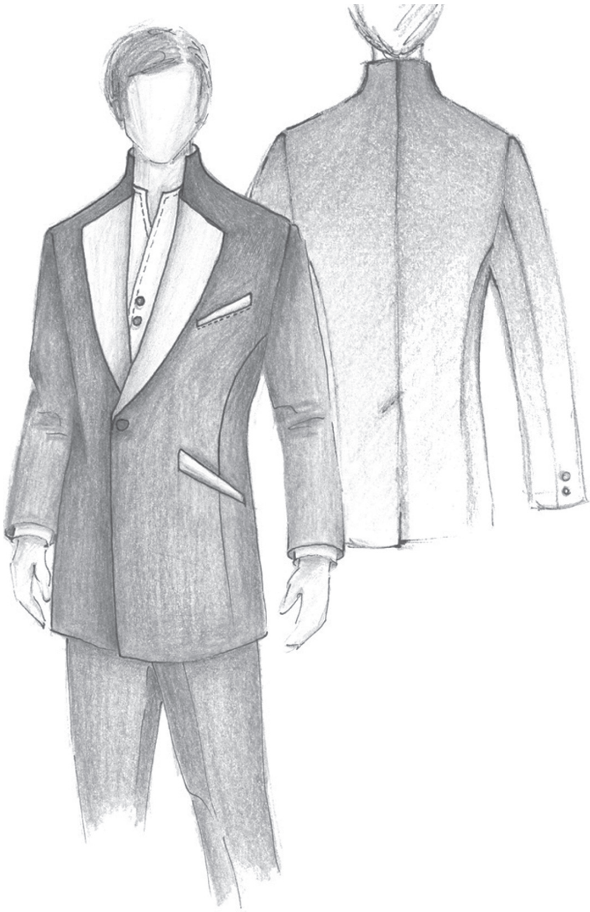
These documents include:

(a) work-order, including data on the programme, number of pieces, basic fabric types, basic characteristics of the model, date, and the person responsible for the manufacture and approval of the proposed product;
(b) model sketch and description, together with product specification;
(c) list of materials; and
(d) quality guidelines.

There are three basic aims regarding the development of technical documents:

1. They should offer information or instructions regarding the operation or action to be performed;
2. They should inform the order for performing the action; and
3. They should be used to register the effects and results of the action performed.

Many other documents, such as job instruction, load chart, manufacturing plan, operational flow chart, and process plan, are used by management to

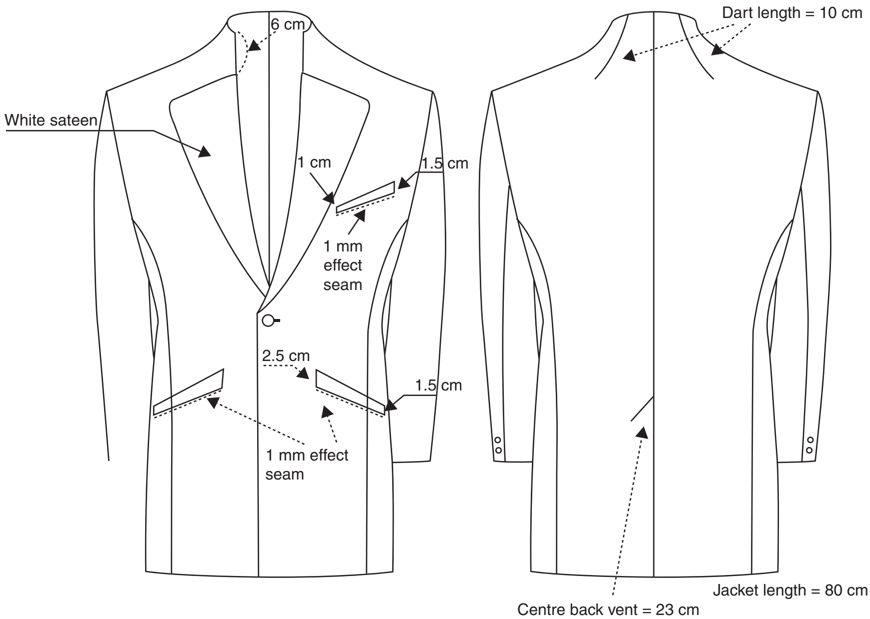


4.3 Fashion sketch of a jacket pattern.

control the operation of the manufacturing process, and some of these will be discussed in a later chapter dealing with the planning of clothing manufacture. Technical documents have to be initially developed. They are often created in electronic form, which allows for easier storage and transmission. The quality of key documentation is very important for manufacturing quality assurance and product quality. It should therefore be carefully and professionally prepared.

4.4.1 Presenting the pattern

A pattern or prototype is defined as an article manufactured as an illustration, and is a representation of the planned or existing article of clothing,



4.4 Technical drawing of a jacket pattern.

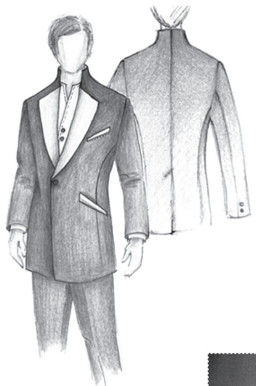
and that includes, apart from the sketch, a detailed description and its key construction characteristics. The so-called technical sketch is used in practice to present the pattern or model, which is based on the idea of the fashion sketch. An example of a fashion sketch from a men's evening wear collection, where the lines of the garment stress the elegant silhouette of men's evening wear, can be seen in Fig. 4.3.

A technical sketch should be made on an adequate scale and accompanied by all the data necessary to present the final product in the intended way, as shown in Fig. 4.4. This must be used to inform all operations so that the design can be transformed into a saleable product. The model sketch should be clear in its construction, as it is supposed to serve as a basis for designing the model's cutting pattern. It should also be aesthetically attractive, as the sketch sells the idea. A model description contains all the key properties that should be manufactured as part of a particular garment, including instructions for the manufacture of lining and interlining.

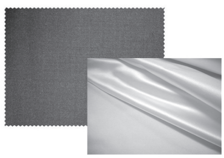
The key construction–technological properties of a model are determined by the control dimensions, whilst model identification is determined by the nomenclature. Apart from the technical sketch and the model's description, the presented model should also contain a product specification. This document collates the basic descriptive information about a particular style, for example, product type, collection, season, size range,

Specification

Size		88	92	96	100	104	108	
Size	ISO	88	92	96	100	104	108	Product type: men's suit jacket
	German	44	46	48	50	52	54	
Chest girth (cm)		88	92	96	100	104	108	Model: Anadin
Waist girth (cm)		76	80	84	88	92	98	Season: Autumn/Spring 2013



Art. 51800 100/E79
Woollen fabric
Twill weave
Weight: 254 gm^{-2}



Art. DG369
Silk sateen

Description

Men's jacket where the lines emphasize the silhouette of evening elegance. Single-chested with one button, with satin lapel without collar. Piped chest and side pockets, vents at the centre back and on the sleeves, sleeve vents with buttonholes and buttons.

On the front and back of the neck curve are darts that form an extended collar or neckline. White, satin lapel is consistent with the shape of piped pockets. Tailored silhouette of the jacket is pointed out at the front and back with decorative seams. Jacket is buttoned up with single button.

Manufacturing instruction

Lapel

White sateen lapel without collar.

Pockets

Piped chest and side pockets, bell-shape with decorative seam. Piped forms of pockets are consistent with the shape of lapels.

Front pieces

Fused front parts with canvas interlining. The neckline with two darts is prolonged in collar without collar seam. Tailored front piece with long vertical seam to emphasize slime line.

Back piece

Two darts, length of 10 cm in the neckline, which allows the extension of collar without collar seam. Centre back seam with vent length of 23 cm.

Sleeves

Classic sleeves with vent and each with 2 buttonholes with buttons

Buttons

1 button at the front edge and 4 sleeve buttons

Thread

100% Polyester core-spun thread

Seam width

Edge seams: 7 mm
Side seams: 15 mm
Other seams: 10 mm
Decorative seams: 10 mm

4.5 Product specification of a man's jacket.

materials, originator, etc., and usually includes a sketch, a brief description, and specific manufacturing instructions. The sketch is not to-scale but gives a visual impression of the front and back details. Hand-written remarks may be added to emphasise particular aspects. A fabric sample supplements the sketch. Product specification usually includes the measurements, which are given for particular sizes. An example of a product specification for a man's jacket can be seen in Fig. 4.5.

4.4.2 List of materials required

A list of materials, otherwise known as the materials list or bill of materials, is a document that comprises all the components of the materials necessary for manufacturing of the product, representing a list of the parts or components that are required to build a product (Martinich, 1997). It lists all the required materials based on the quantities required for one item, and determines the following:

(a) The physical (material) structure or composition of the product and its components; and
(b) The quantities of particular components in the product (normative quantities).

Apart from the specification of the required materials, the list of materials also contains:

- clothing designation and cutting-pattern type designation;
- data on the basic raw material's fabric content;
- design;
- data on the auxiliary fabric's raw material content;
- dimensional data: width (of the fabric), mass (of the fabric), linear density (in tex for the thread), diameter (for buttons), length (for zippers), etc.;
- basic fabric sample;
- other data (possible embroidery, waistband – type, colour and width); and
- conditions for cleaning and care.

The data from the list of materials are used to calculate the total requirements for various materials, which are then used to compose the materials requirement list. As soon as the product is approved for production, this document is supplied to the purchasing department.

Since fabrics are the base of an efficient manufacturing data system, it is necessary to introduce a unique system for designating them, to ensure clear and easy classification and identification of the fabrics or articles of clothing. A designation, or code symbol, is used for this purpose, consisting of a system of signs, that is, classification and information designations (letters and numbers), as well as the identification designation (consecutive number). The identification part of the code is intended for the unambiguous designation of products, so as to prevent mistaken identity within a group, whilst the classification part is used to denote those groups of identical or similar products.

4.4.3 Manufacture quality requirements

Over recent decades, the view of quality has changed dramatically. Quality as a term cannot be accurately defined today, because quality is determined by the customer and means conformance to requirements. Quality is, therefore, a question of achieving a degree of inherent characteristics regarding a set of requirements, and is always relative to a set of requirements. According to the Business Dictionary, quality (in manufacturing) is defined as ‘a measure of excellence or a state of being free from defects, deficiencies, and significant variations, brought about by the strict and consistent adherence to measurable and verifiable standards to achieve uniformity of output that satisfies specific customer or user requirements’. The ISO 8402:1986 standard defines quality as ‘the totalities of the features and characteristics of a product or service that bears its ability to satisfy stated or implied needs’.

Because quality is directly linked with profitability, emphasis on quality must start at the very beginning, that is, during the design stages of a product or a process, and continue throughout the production phase. This is very important for clothing manufacturing, as clothing quality is reflected in both the materials used and the quality of manufacture, and the suitability of the materials used (fabrics and auxiliary materials) is evident in the quality of the fabrics, including their characteristic properties, which can be:

- basic;
- useful or functional;
- processing; and/or
- visually aesthetic (Geršak, 1996, 1998).

At the same time, manufacturing quality can be seen in the quality of the individual ‘making-up’ operations performed, as well as in the quality of the finished clothing. Quality awareness has to be integrated into every activity, from design to delivery. The quality requirements should be handled from the point of view of a case study, as a puzzle that has to be solved.

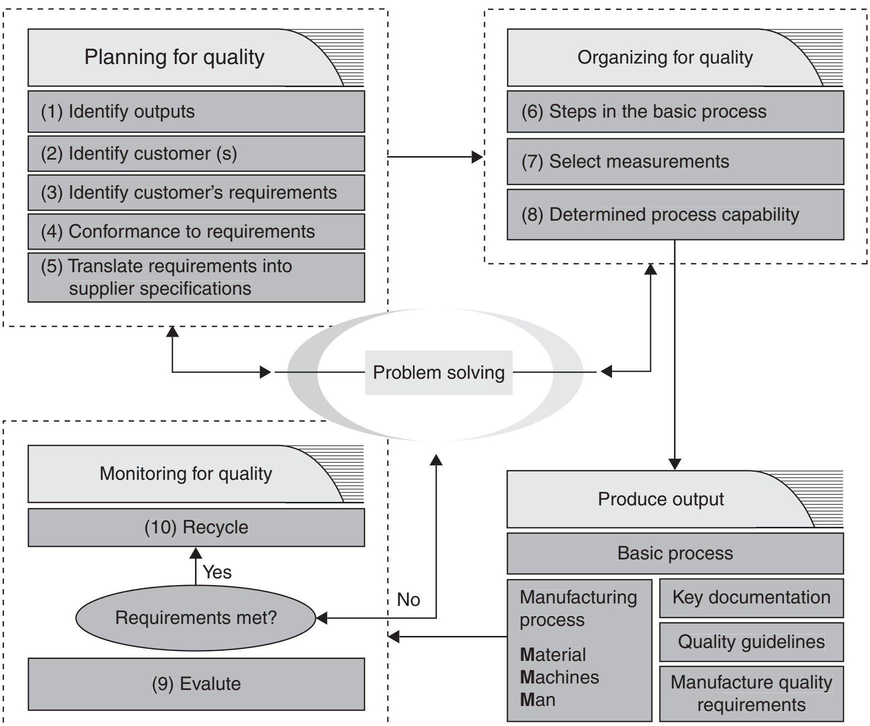
Considering the manufacturing quality requirements mentioned above, for which it is necessary to establish suitable and effective criteria for technical quality assurance, the strategy for dealing with manufacturing quality should contain the following basic components:

- Define the quality characteristics of clothing regarding the manufacturer’s view of quality (adherence to specifications), and the customer’s view, or the so-called ‘fitness for use’ (i.e., quality of design, quality of conformance, availability, safety, field use, etc.);
- Unambiguously define a set of appropriate product quality requirements, with tolerances;
- Unambiguously define a set of appropriate quality requirements, for which no tolerances are allowed;
- Unambiguously define quality requirements for implementing quality control, including those techniques for measuring the degree of conformity to these requirements; and
- Invest in prevention so as to consolidate and improve such results.

The problem is rather complex, because quality is not a static concept but a dynamic one. It is an intensive analysis of manufacturing quality and the quality of the finished clothing, by stressing developmental factors in relation to quality. Thereby it begs the important question: does improving a product's quality cost money or save money? Much controversy surrounds this seemingly straightforward question. The answer is often unknown, since the necessary analyses are often missing or inadequate.

One of the critical factors that can affect quality is an emphasis on problem identification. The fact that about 85% of all quality problems require management to take the initiative and change the process, and only about 15% of quality problems can be controlled by the workers, reflects the contrasting nature of quality requirements. It is therefore necessary, first of all, to identify the problem and to determine its cause. Because quality requirements are conducted during product and process planning, when changing a process it is necessary to clearly articulate those quality requirements that would contribute to the success of the quality changes.

The quality improvement process from an operative point of view, as shown in Fig. 4.6, illustrates that the organisation places more emphasis on a

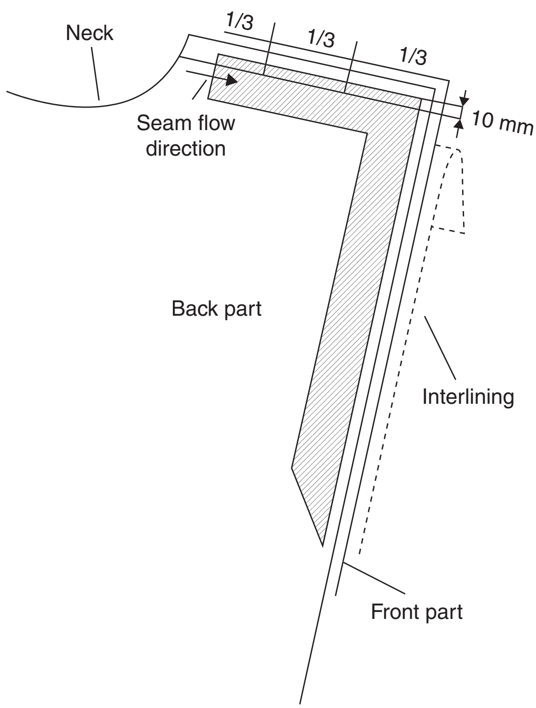


4.6 The quality improvement process.

quality process than on a quality product and, therefore, is actively pursuing quality improvements through a continuous cycle.

The process is comprehensive, and here we shall limit ourselves to only presenting the case of manufacturing and product quality requirements as part of quality planning. The technique can only be effective when applied early on, when designing the product and the process system.

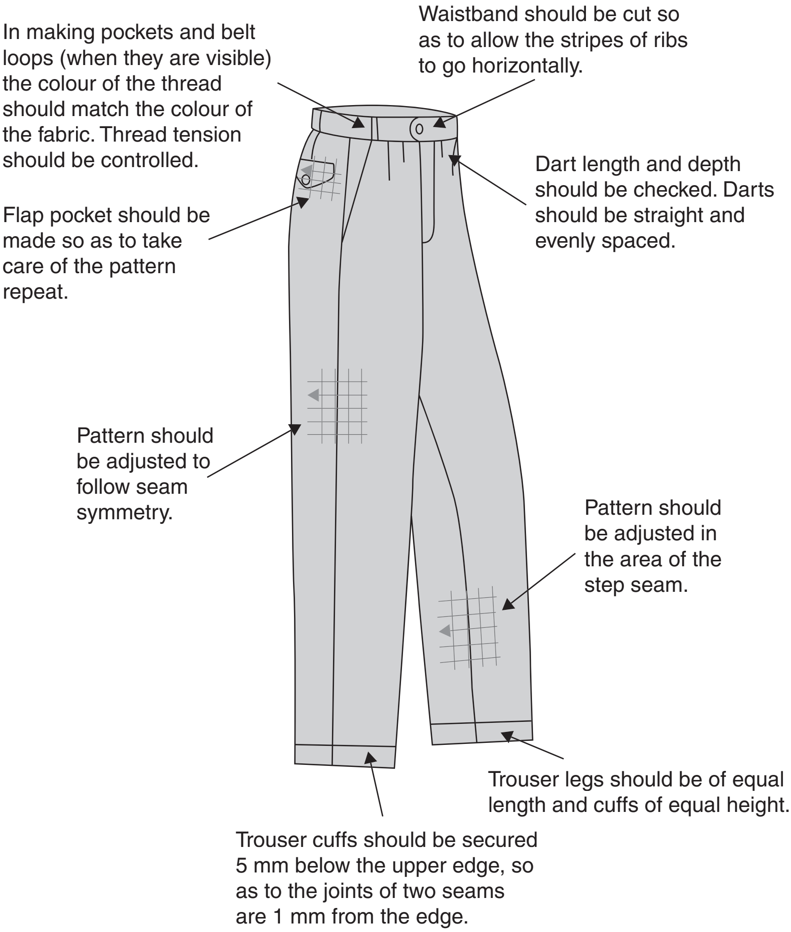
The basic approach is to eliminate the causes of faults, rather than just correcting faulty work. It is necessary to compose a list of quality requirements, that is, a document comprising a detailed definition of quality requirements for particular operations (requirements for performing sewing operations, formability, overfeeding, etc.), as well as requirements for the finished clothing's quality. This is necessary in order to attain the pre-planned quality level of the clothing to be made, as determined within the process of collection development. For this purpose, all of the necessary measurements during product development are documented to provide quality targets for subsequent manufacturing. The quality of the finished clothing can be quantitatively evaluated using pre-determined clothing appearance quality elements, which include matching-pattern repeat, symmetrical seams, quality of the piping, etc. An example of quality requirements when performing the operation of sewing the shoulder-seam on a man's jacket can be seen in Fig. 4.7.



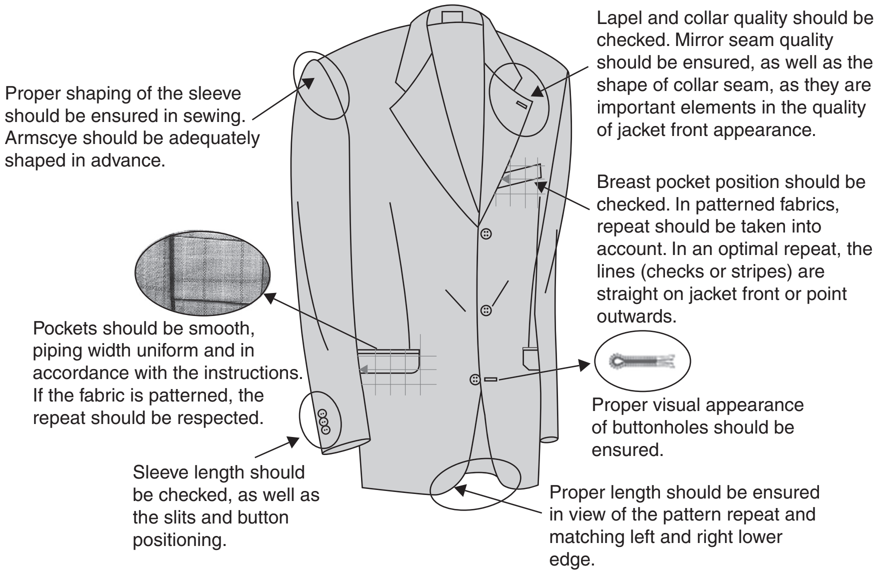
4.7 Quality requirements in the operation of sewing a side seam.

The quality requirements for a finished article of clothing should also be precisely determined, and be based on the following activities:

- Defining the grades for visually evaluating the clothing's fit during try-ons.
- Analysing in detail and defining the criteria for individual evaluations, together with pictorial representations of the differences between grades.
- Shaping a system for evaluating the quality of manufacture, this system being divided into two parts. The first concerns evaluating the quality when performing individual operations, and the second is based on visual evaluation of clothing-fit during try-ons (Geršak, 2003).



4.8 Quality requirements in the manufacture of men's trousers.



4.9 Quality requirements in the manufacture of an individual details in a man's jacket.

- Dividing the product during evaluation into individually evaluated segments, whilst previously preparing the documents to be used when controlling the evaluation (Podlesek, 2003).
- Determining those operations that most strongly impact clothing quality.
- Determining the compilation of instructions regarding quality guidelines.

An example of the requirements necessary for ensuring quality when manufacturing men's trousers can be seen in Fig. 4.8, whilst Fig. 4.9 shows the quality requirements regarding individual details during jacket manufacture. The quality improvement process, and clearly articulating one's quality requirements, all assist in involving operators and supervisors to accept personal and collective responsibility for quality.

4.5 Conclusions

As has been shown, the planning of clothing production is complex, but constitutes an extremely flexible and highly effective approach to multidisciplinary management.

Although the vast majority of publications deal generically with production planning and organisation, as well as production management and control, there are several notable exceptions which distinguish between work nature, product development, and production planning. This chapter has discussed the key terms and roles of clothing production planning and organisation, and has explained design analysis and activity planning, including development documents, whilst the specificities of planning pattern making and cutting, planning clothing manufacturing, and clothing production management will be discussed in the following chapters. It has also stressed the importance of manufacturing quality requirements, including a case study. The quality requirements include all those activities that organisations use to direct, control and coordinate quality, because quality control is a set of activities intended to ensure that quality requirements are actually being met.

4.6 References

Collins, P. and Glendinning, S. (2004), Production planning in the clothing industry: Failing to plan is planning to fail, *Control*, **1**, 16–20, iomnet.org.uk.

Eversheim, W. (1989), *Organisation in der Produktionstechnik*, Band 3 Arbeitsvorbereitung, Düsseldorf, VDI Verlag GmbH.

Geršak, J. (1993), *Information System of Quality Assurance in the Apparel Manufacturing*, Proceedings of International Conference Design to Manufacture in Modern Industry DMMI'93, Maribor, Faculty of Technical Sciences, Department of Mechanical Engineering, II/707–710.

Geršak, J., Stjepanović, Z. and Podlesek, J. (1994), *Work Preparation and Information Flow in Clothing Manufacture Process*, Entwicklungspotential in Energie-, Material- und Informationsfluss, (DWI Reports, 113), Aachen, Deutsches Wollforschungsinstitut an der Technischen Hochschule Aachen, 457–465.

Geršak, J. (1996), *Fabric Quality Requirements – Costs or Savings* (in Slovenian), Book of Proceedings Garment Engineering '96, Maribor, University of Maribor, Faculty of Mechanical Engineering, 37–46.

Geršak, J. (1998), *Is Garment Industry Familiar with Fabrics?* (in Slovenian), Book of Proceedings Garment Engineering '98, Maribor, University of Maribor, Faculty of Mechanical Engineering, 1998, 38–44.

Geršak, J. and Zavec Pavlinić, D. (2000), *Creating a Knowledge Basis for Investigating Fabric Behaviour in Garment Manufacturing Processes*, Annals of DAAAM for 2000 & Proceedings of the 11th International DAAAM symposium 'Intelligent Manufacturing & Automation', Vienna, DAAAM International, 155–156.

Geršak, J. (2003), Investigation of the impact of fabric mechanical properties on garment appearance (in Croatian), *Tekstil*, **52** (8), 368–378.

Geršak, J. (2008), *Study of the Asymmetric Behavior of the Fabrics in a Produced Garment*. 4th International Textile, Clothing & Design Conference, *Magic World of Textiles, Book of Proceedings,* Zagreb, Faculty of Textile Technology, University of Zagreb, 587–592.

Kawabata, S., Niwa, M., Ito, K. and Nitta , M. (1990), Application of objective measurements to clothing manufacture, *International Journal of Clothing Science and Technology*, **2** (3/4), 8–31.

Kawabata, S., Ito, K. and Niwa, M. (1992), Tailoring process control, *Journal of Textile Institute*, **83** (3), 361–373.

Kleindienst, J. (2008), Production control in piece production industry (in Slovenian), *Ventil*, **14** (4), 360–365.

Lewis, J.P. (1995), *Project Planning, Scheduling & Control*, New York, McGraw-Hill.

Martinich, J.S. (1997), *Production and Operations Management – An Applied Modern Approach*, New York, John Wiley & Sons, Inc.

Podlesek, J. and Geršak, J. (1993), *Project Organization – Flexibly Organized Business System in Clothing Industry*, Proceedings of International Conference Design to Manufacture in Modern Industry DMMI'93, Maribor, Faculty of Technical Sciences, Department of Mechanical Engineering, II/711–718.

Podlesek, J. (2003), Evaluating garment manufacturing quality on the example of men's jacket (in Croatian), *Tekstil*, **52** (4), 166–175.

Zavec Pavlinić, D. and Geršak, J. (2004), Design of the system for prediction of fabric behaviour in garment manufacturing processes. *International Journal of Clothing Science and Technology*, **16** (1/2), 252–261.

5

Planning of clothing design, pattern making and cutting

DOI: 10.1533/9780857097835.105

Abstract: In this chapter, garment-pattern construction, pattern making and fabric utilisation are discussed. The chapter first discusses garment-pattern construction, and pattern-pieces and their preparation. It then explains the cutting-marker process, before defining cutting-marker parameters that impact on the quality of the garment parts to be cut. The chapter then discusses technological requirements when arranging pattern-pieces in a cutting-marker. Finally, the chapter describes the factors affecting efficient cutting-marker utilisation.

Key words: pattern construction, cutting-marker, cutting-marker parameters, efficiency, fabric losses, fabric utilisation.

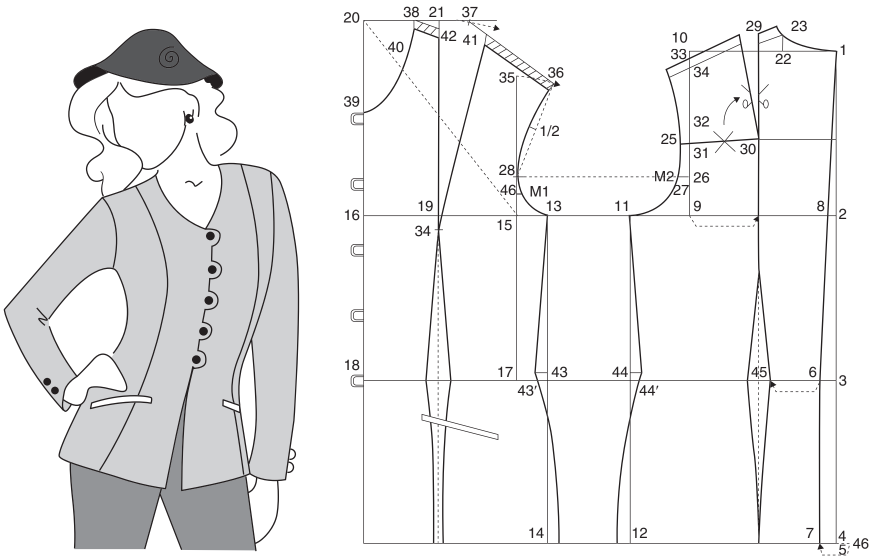
5.1 Introduction

In the first two chapters we reviewed clothing classification systems, and clothing sizing and designation systems, whilst in the third chapter we focused on product and collection development. In the fourth chapter we defined the role and functions of clothing production planning as major factors for the continuous and efficient operation of clothing manufacturing. In addition, we identified the necessary planning documentation and defined the manufacturing quality requirements to assure successful clothing production. This chapter reviews clothing-design analysis and activity planning, as the first stage in clothing production planning. This stage includes all activities from garment-pattern design, grading and preparation of markers to material requirements.

5.2 Constructing garment patterns

Constructing garment patterns is a complex process that is performed, for particular types of garments, on the basis of (Eberle *et al*., 1993; Knez, 1994):

- body proportions;
- pictograms;
- body measurements;



5.1 Construction of woman's jacket, front and back parts.

- garment-sizing systems and size designation of clothes;
- back and chest widths;
- main body measurements;
- construction measurements; and
- additional measurements.

A pattern is a diagrammatic representation of the way a garment part is constructed, which forms the working plan for its manufacture. An example of the basic pattern construction for a woman's jacket in garment size 38 can be seen in Fig. 5.1.

As garments are generally composed of the basic fabric, lining,[1] and interlining,[2] they require a pattern for the basic fabric, which will then form the basis of the pattern for the linings. Lining patterns should always include

1 **Lining** – is a fabric that covers the inside of a piece of clothing. The qualities required by a lining fabric are that it be lightweight and non-shrink, with a close weave structure and a smooth surface finish.

2 **Interlining** – is a fabric sewn or fused inside a garment to give it shape and stability. The most important quality of an interlining is that it should provide stability and shape to an item of clothing without changing the inherent characteristics of its fabric, particularly its handle. The interlining for clothing has to be resilient and must not shrink when dry cleaned, or in some cases when washed. Woven, non-woven and knitted fabrics are used for interlinings. They can be further categorised into non-fusible and fusible.

what is known as 'ease'. The lining should never pull the clothing out of shape or cause wrinkles. The ease may have to be increased, depending on the spread or stretch in the clothing fabric (Aldrich, 2002).

Basic pattern construction and modelling can be performed either in the conventional manner or by using a computer system designed for the purpose. In the conventional manner, the construction, modelling and modification of garment pattern-pieces are done manually, whilst grading (i.e. stepwise increase or decrease pattern-pieces) can be done manually or using appropriate computerised systems. When garment patterns are constructed using a computer (with such systems offering construction, modelling and modifications of the basic pattern, as well as simultaneous grading of individual pattern-pieces into target sizes), it is necessary to do the following:

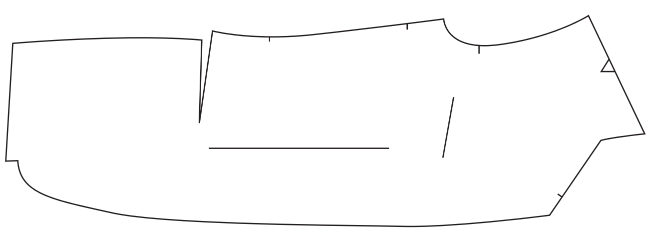
- Systemise the pattern-pieces and models;
- Prepare the pattern-pieces;
- Determine the type of material to be used; and
- Define the cutting-marker parameters.

Contrary to the above, in conventional construction preparation, which includes the construction, modelling, and modifications of garment pattern-pieces manually, it is necessary to prepare the pattern-pieces in advance, which can be used later during computerised processing.

5.3 Pattern-pieces and their preparation

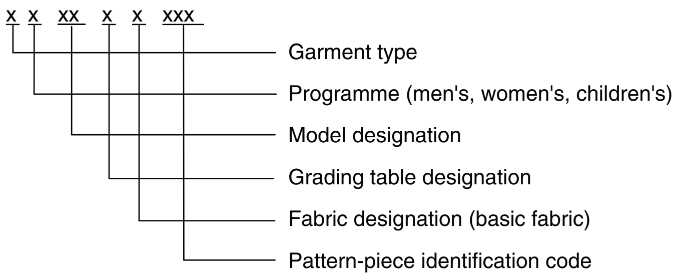
A pattern-piece can be defined as a component of a garment pattern constructed on the basis of technological-construction requirements, or a component of a garment part cut from a particular template; see Fig. 5.2. A pattern-piece should contain a designation (code), size designation, marks for the positions of darts, folds, pockets and control incisions, as well as an indication of yarn direction (warp yarns or loop column in the case of knitted fabrics).

Pattern-piece designation should be composed so as to indicate the type of fabric used (or other sheet material, such as leather, fur, etc.) for the pattern-piece in question and the model to be manufactured, the designation



5.2 Pattern-piece of a jacket.

of the appropriate grading table, the name of the model, and the identification code that indicates particular model pattern-pieces. A nine-digit designation is often used (although contemporary systems enable larger designations to be used, up to 13 digits), where the first six digits indicate the model, whilst the last three describe the pattern-piece. The pattern-piece designation therefore assumes the following form:



5.3.1 Adding seam and hem allowances

The seam allowance, which is defined as the distance between the seam line and the cut edge, should be determined for individual pattern-pieces, with respect to their clothing models. Within the seam allowance is a defined measure, which varies from enterprise to enterprise but should be defined uniformly in every production. The seam allowance can be, depending on the production programme and the seam position, between 7.5 and 15 mm (Schierbaum, 1993). The standard seam allowance measurement is 10 mm, but high quality garments (e.g., a jacket) may have 15 mm seams on the back and side seams. Intricate seams, such as welt seams, will also vary in size. The hem allowances are also different. For example, hem allowances on the body and sleeve of a coat are approximately 40 mm.

5.3.2 Preparation of pattern-pieces for digitising and grading

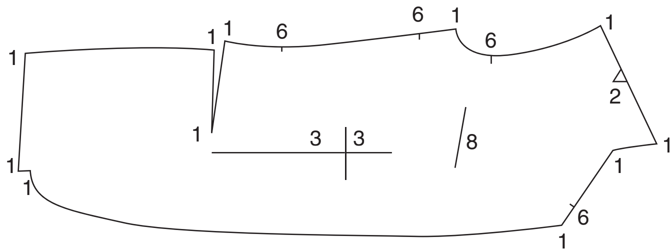
Garment pattern-pieces are generally formed of particular geometrical shapes that cannot be easily stored in a computer memory but have to be converted into a form appropriate for computer notation, that is, an electronic form that is appropriate for further computerised processing. There are various actions to be taken in the preparation of pattern-pieces, their storage and computerised grading (Rogale and Polanović, 1996; Ujević *et al*., 2000; Aldrich, 2004).

An important step is the systematisation of those pattern-pieces and model names necessary for computerised pattern-piece grading and cutting-marker planning; all the data necessary for these two actions should be systematically included in adequate databases, which involve:

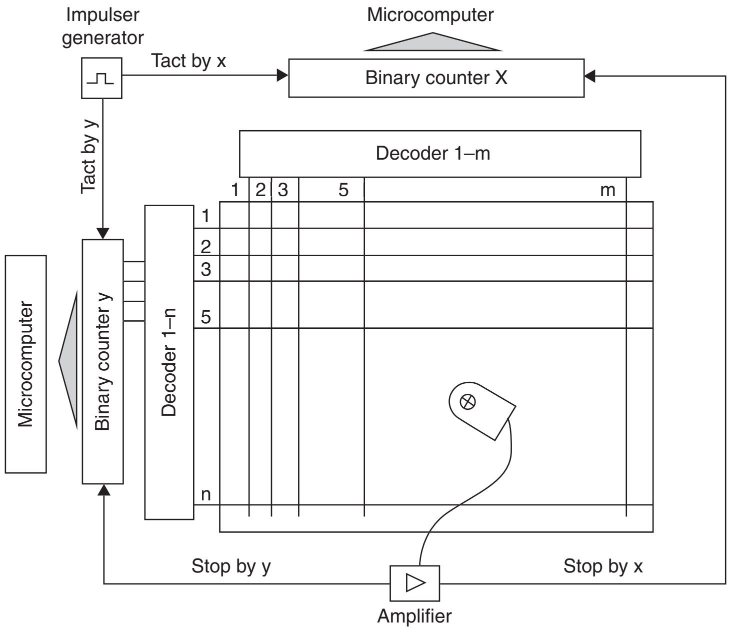
- basic pattern-pieces;
- grading rules;
- garment models; and
- cutting-markers.

Pattern-piece preparation for digitising involves:

- defining pattern-piece contours, being composed of a number of different lines, each starting with one and ending with another main point;
- decomposing pattern-piece contours;
- determining segment types, where those with straight lines are defined by their first and second main points, whilst those with curved lines are defined by their starting and ending points, as well as those with auxiliary points, which further define the shape of a particular curve;
- determining auxiliary points in the areas of curved segments;
- defining those border garment sizes for which grading is to be performed;
- defining those types of garment sizes for which grading will be performed within the border areas previously determined;
- designating the main and auxiliary points on the pattern-pieces contour, as well as inner points;
- determining the types (TIPs) and manner of moving (COD) the main points, where the main point TIPs define various designations, warp yarn direction, darts, pockets, folds, etc. Inner contours and inner points can be distinguished from the point of view of main point TIPs (see Fig. 5.3), whilst COD describes the interval of size deviation from the basic pattern-piece of the basic size, towards particular measurement sizes (Rogale and Polanović, 1996).



5.3 Types of point TIPs on a jacket basic pattern-piece.



5.4 Schematic diagram of a digitiser used for recording and reading-off the coordinates (Rogale and Polanović, 1996).

Pattern-pieces are digitised using a digitiser[3] (Fig. 5.4), which physically transforms geometrical shapes of pattern-pieces into a series of numbers that are appropriate for computerised processing. In order to perform this process, the pattern-piece is attached to the digitising tablet and the position of each marked pattern-piece contour point is recorded, in a clockwise direction. The digitiser is linked to a microcomputer, which records data on the position of each point. Pattern-pieces can be digitised in three ways (Rogale and Polanović, 1996):

1. Digitising is done on a previously prepared grid of basic size pattern-pieces, highlighting the biggest and the smallest (Fig. 5.5). The coordinates of the main and auxiliary points, as well as the grading values, are stored by the computer.
2. Digitising with the simultaneous formation of a grading database. Digitising is again performed from the previously prepared pattern-piece

[3] **Digitiser** – an apparatus for recording and reading off the coordinate points of geometric shapes; it enables the data on cutting-part geometric shape to be transferred into a digital form.

5.5 Pattern-piece digitising.

contour grid. However, grading data are shaped during digitising and are stored in the database containing this type of information.

3. Digitising referring to the designation of the memorised grading rule values. The basic size is digitised for this purpose.

The pattern-pieces are graded when the digitising and control processes are complete, by employing previously determined grade rules[4] (also called grading rules). Grading means the stepwise increase or decrease of a master pattern-piece to create larger or smaller sizes. The direction and values of the shift for each main point position during grading are defined at each main point of each segment. In order to determine these shifts, a local coordinate system is used, its starting point being the main point of the contour segment for the basic clothing size. The incremental values of main point coordinate increase are the so-called abscise increments (Δx) and ordinate increments (Δy), whilst decreasing is defined by abscise decrement (Δx) and ordinate decrement (Δy). The main point increments and decrements, with their appropriate values, compose so-called variable data (Rogale and Polanović, 1996). When digitising is over, modifications and digitising control have been performed successfully and the grading rules are stored, the digitised pattern-pieces are stored as well.

5.3.3 Preparation of pattern-pieces for model definition

Garment model defining is started when the preparation of pattern-pieces has been completed, that is, digitising, confirmation of variable data on the

[4] **Grade rule** – is the instruction across a range of sizes. Grade rules can be calculated from size charts or from previous patterns. They can be placed individually on pattern points or accessed from grade-rule libraries. A grade-rule library is compiled of numbered grade rules used at the grade points (Aldrich, 2002).

pattern-pieces main points for basic fabric, and modifications for the other pattern-pieces, such as pattern-pieces for the lining and interlining. The garment model includes all the pattern-pieces necessary for manufacturing an article of clothing. These are:

- pattern-pieces for the basic fabric;
- pattern-pieces for the lining;
- pattern-pieces for the fusible interlining;
- pattern-pieces for the auxiliary fabrics (pockets, etc.); and
- templates to be used when marking the positions of pockets, button-holes, etc.

A model is defined by its name and the list of pertaining pattern-pieces, by the number of repeated pattern-pieces, and by the type of fabric used.

Apart from those requirements that define the basic characteristics of a particular pattern-piece, each pattern-piece should also contain symbols that clearly determine its position within the cutting-marker. For example, the

Symbol	Meaning
│	Direction indicated on the pattern-pieces should be parallel to the system of warp yarns in the marker.
┼	One of the directions indicated should be parallel with the system of warp yarns.
✳	Pattern-piece can be randomly laid onto the marker.
↓	Designates main pattern-piecess that should be laid onto the marker for fabrics with oriented direction, according to the predetermined rules.
⇣	Designates those pattern-pieces (not the main ones) that should be laid onto the marker, for fabrics with oriented-direction, according to the predetermined rules.
5 ↗	Designates the direction in which a pattern-piece can be moved for a predetermined number of mm, as related to the warp threads in the marker.
1/2 ⇒	Designates corrections added to pattern-pieces for those fabrics with a pattern repeat. Correction allowance size depends on the size of pattern repeat in question.

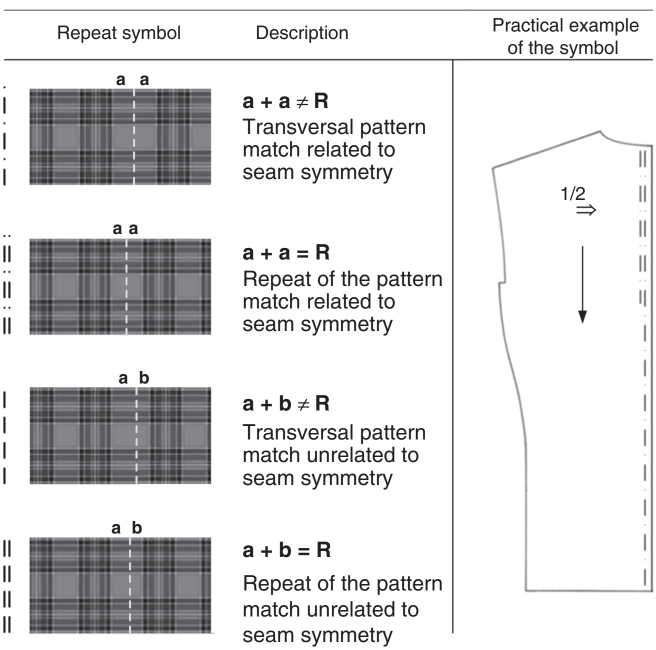
5.6 Symbols used to mark the positions of pattern-pieces on a cutting-marker.

quality of a finished article of clothing is affected significantly by the position (direction and orientation) of a pattern-piece into a cutting-marker. The symbols in Fig. 5.6 are used to arrange pattern-pieces into a cutting-marker (Steuckart, 1974).

When preparing model pattern-pieces from patterned fabrics, that is, fabrics with checks, stripes or other patterns, it is necessary to determine the requirements for matching pattern repeats. The quality of a product is affected significantly by the accuracy of pattern matching, and the positions of the components during matching pattern repeats in a finished article of clothing can be:

- transversal pattern match related to seam symmetry;
- repeat of the pattern match related to seam symmetry;
- transversal pattern match regardless of seam symmetry; or
- repeat of the pattern match unrelated to seam symmetry.

The symbols in Fig. 5.7 can be used to designate pattern match, or pattern-repeat match, for pattern-pieces in the area of the seam. During spreading it is necessary to match the pattern exactly at each end of the lay and in every ply.



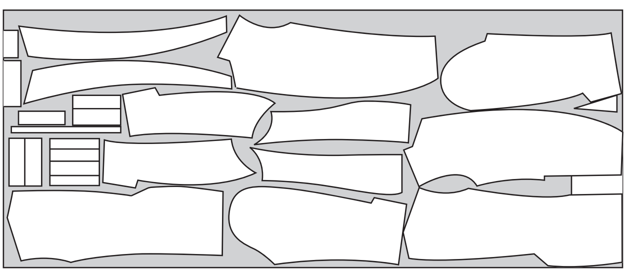
5.7 Types of pattern matching.

5.4 Pattern cutting-markers

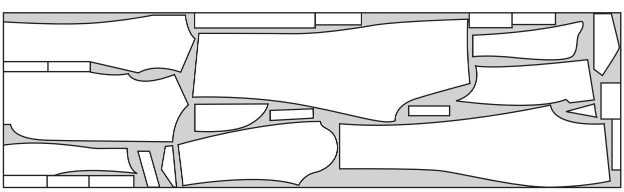
The cutting-marker is a combination of evenly-distributed pattern-pieces, following predetermined cutting-technological requirements, of one or more clothing sizes for a particular model, done on a previously determined paper width, on a fabric, or some other material, which stands perpendicular to cutting (except where leather is concerned), and is used for fabric cutting (Fig. 5.8). Individual pattern-pieces should be arranged by their designations (which indicate the position of a particular pattern-piece within the cutting-marker) so as to utilise the cutting-marker to its fullest.

Cutting-markers can be, depending on the structure of the pattern-pieces in the marker, half cutting-markers or whole cutting-markers. Half cutting-markers include half of the pattern-pieces for one or more garment sizes of a particular model (e.g., the right side – Fig. 5.9), whilst the other half is a mirror-image of the presented cutting-ply. These are used for folded or tubular fabrics, and for fabrics that are spread face to face. The whole cutting-marker includes all the pattern-pieces of a single or multiple garment sizes, for a particular model (Fig. 5.8), and is used for open-width fabrics.

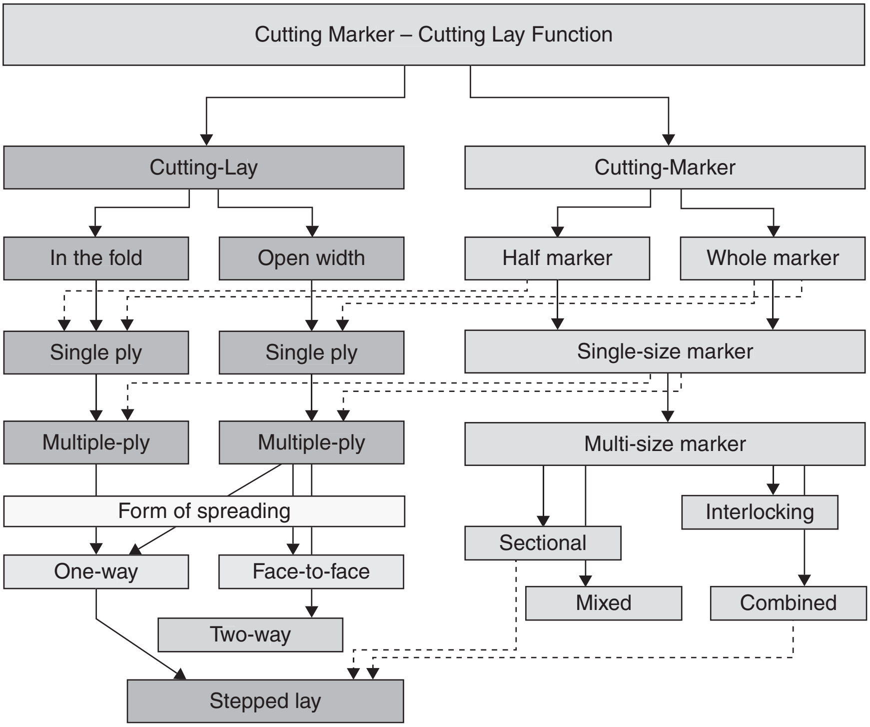
Various types of cutting-markers are used in practice, depending on the number of clothing sizes, their structural distribution within the cutting-marker, the characteristics of the fabrics used, and the technological requirements of the cutting operation. The most common cutting-markers,



5.8 The whole pattern cutting-marker.



5.9 Half pattern cutting-marker.



5.10 Pattern cutting-marker types according to the structures of the cutting-lays.

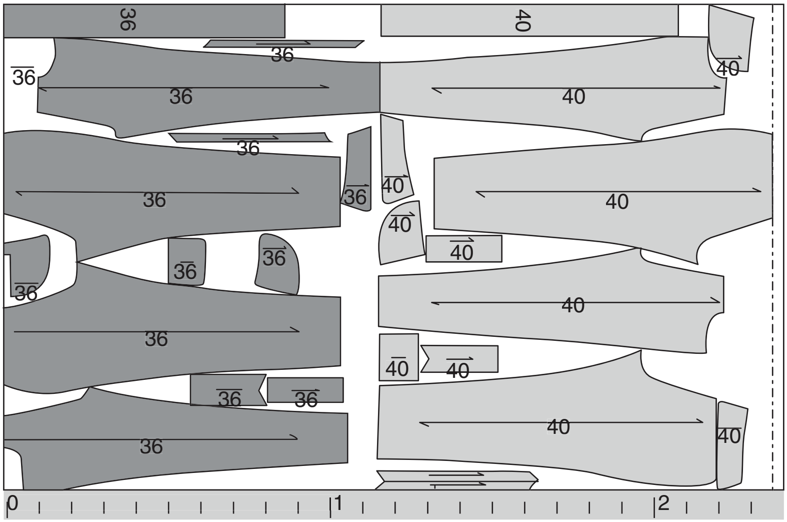
as regards laying the fabric in the cutting-lay[5] and the type and structures of the cutting-lay, can be seen in Fig. 5.10. These are:

(a) single-size cutting-markers;
(b) multi-size cutting-markers.

Multi-size cutting-markers can be of equal size (a combination of two or more units of the same garment size, i.e., 38 + 38) or of different sizes (a combination of two or more units of different clothing sizes, i.e., 38 + 40), whilst according to the pattern-pieces' structure, cutting-markers can be:

- chained or sectional;
- interlocking;
- mixed; or
- combined.

[5] **Cutting-lay** is defined as a lay consisting of two or more plies of fabric spread one above the other, on which a cutting-marker is placed.



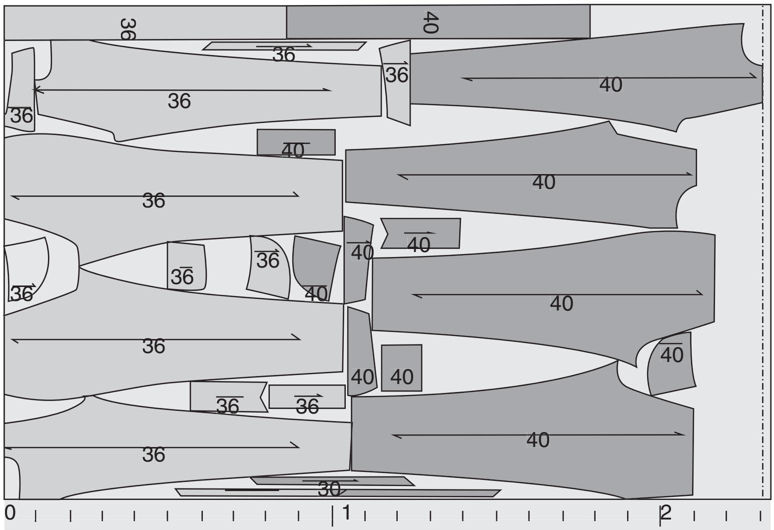
5.11 Chain cutting-marker.

A chain or so-called sectional cutting-marker is composed of two or more units or sections of the same or different garment sizes, following one another and linked perpendicularly (Fig. 5.11). Each section contains all of the pattern-pieces for a single-size.

An interlocking cutting-marker is composed of two or more units of the same or different garment sizes, following one another so that the pattern-pieces complement each other at the crossing-line from one unit to the next (Fig. 5.12). As the pattern-pieces cross the borders between units, the interlocking cutting-marker is more efficient than the chain cutting-marker, as shown above.

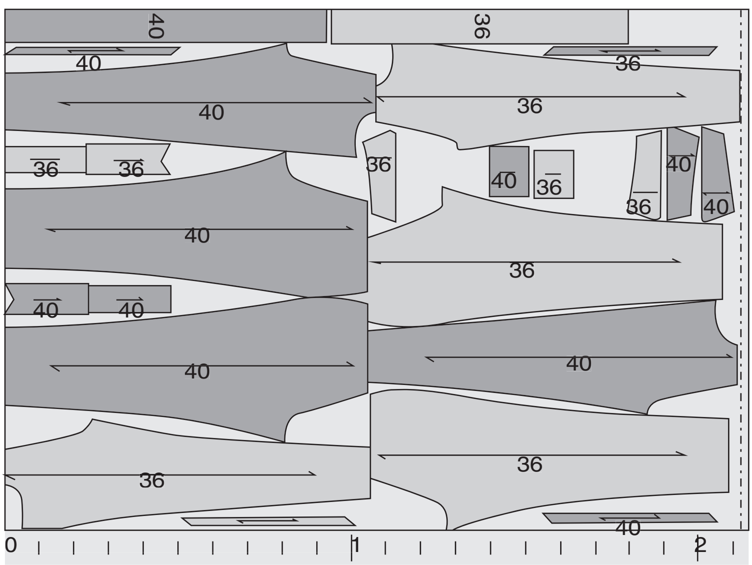
A mixed cutting-marker is composed of two or more units of the same or different garment sizes, whilst pattern-pieces are randomly (but still following the cutting-technological rules) distributed so as to exploit the cutting-marker to its fullest, as shown in Fig. 5.13. Such an arrangement generally utilises the material best.

A combined cutting-marker is a combination of chain and mixed cutting-marker, comprising at least three (or more) units of different garment sizes, whilst two among them, represented in the same work-order with the same per cent proportion, can be joined in a mixed cutting-marker. Individual units follow one another and are perpendicularly linked (Fig. 5.14).



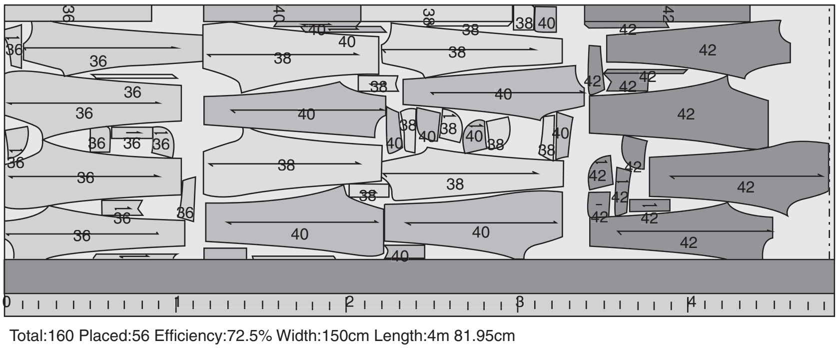
Total:156 Placed:28 Efficiency:74.4% Width:150 cm Length:2m 30.88cm

5.12 Interlocking cutting-marker.



Total:156 Placed:24 Efficiency:78.4% Width:150cm Length:2m 12.19cm

5.13 Mixed cutting-marker.



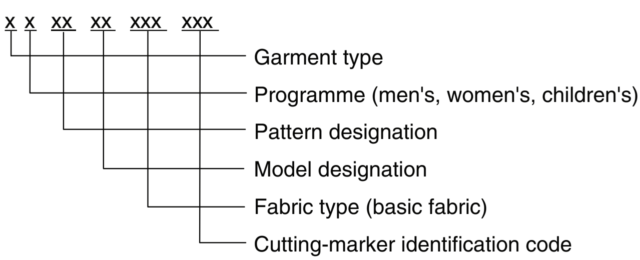
5.14 Combined cutting-marker.

5.5 Designating cutting-markers

Cutting-markers are made for various models and clothing sizes, as well as for different fabric types and widths, which is why precisely designated pattern-pieces and cutting-markers are so important. A cutting-marker should contain:

- model designation;
- clothing size designation;
- cutting-marker width in relation to fabric width;
- cutting-marker length;
- fabric type;
- cutting-marker utilisation; and
- cutting-marker designation.

The cutting-marker designation should indicate the type of clothing to be made, fabric type (or other flexible sheet material used), and model designation and identification codes. The designation usually has the following form:



5.6 Defining fabric and other parameters

Since the cutting-marker, as a combination of cutting-technological requirements for evenly-distributed pattern-pieces, is used as a basis for directly cutting the fabric lays and transforming them into garment parts, the parameters need to be precisely defined before the cutting-marker is made. Apart from attributing names and designations to a cutting-marker, all parameters should be defined that directly impact the quality of the garment parts to be cut, the economy of manufacture and attaining the target quality level of the garment to be made. These parameters are:

- the nature of the fabric or other sheet material type that will be used to make the model;
- the manner of spreading the fabric into the cutting-lay;
- fabric pattern, if any;
- fabric width;
- fabric dimensional stability;
- fabric elasticity;
- position of the pattern-pieces within the cutting-marker; and
- the models and garment sizes that are included in a cutting-marker.

5.6.1 Defining the type of fabric and form of spreading

Prior to making a cutting-marker, it is necessary to define in detail the types of materials to be used (i.e. basic fabric, interlining, lining), as determined by the model description, since cutting-markers are made separately for the basic fabric, lining and interlining. Designations used in the material storage document are also used for this purpose. Additionally, it is necessary to select the forms of each fabric piece that relate to the fabric package, respectively the characteristics of the fabric and the method of spreading. The forms of fabric piece that can be used are as follows:

- open fabric or open-width fabric (may vary from less than 75 cm wide to over 300 cm, especially with knitted fabrics);
- folded or doubled fabric (traditional form for the woollen and woollen mixture fabrics used in tailored garments; its width commonly varies from about 70 to 80 cm folded); or
- tubular knitted fabric (usually used for the manufacture of garments such as sports shirts or tee-shirts; in specialised cases the fabric width is that required for the shirt body).

According to the direction of the fabric's ply into a lay, the forms of spreading can be:

- one-way: each ply of fabric is laid the same way up, with the grain; this form is used for fabrics with a grain or a directional pattern;
- face-to-face: the plies are laid in pairs, face to face; the grain or pattern runs in the same direction; or

- two-way: the plies are laid continuously from left to right and right to left; this form cannot be used for fabrics with a grain or a directional pattern.

The form of spreading fabric into cutting-lays influences the type of cutting-marker to be made (i.e. half or whole cutting-marker). With folded fabric the cutting-marker contains only a half set of the pattern-pieces (half cutting-marker), since the fabric by its nature is spread face to face.

5.6.2 Defining the fabric pattern

From a visual point of view, textile fabrics differ by:

- pattern type (single colour, striped, checked or plaid); and
- orientation (with respect to surface nap, asymmetric surface texture, etc.).

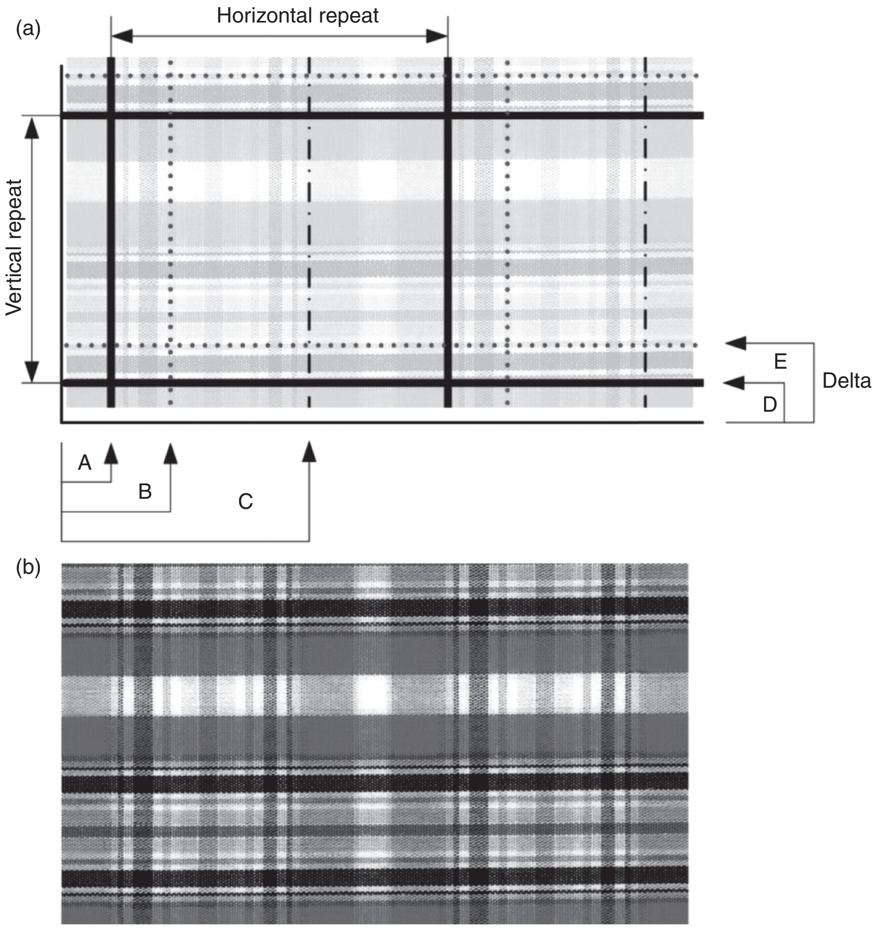
In respect of particular patterns, textile fabrics can be divided into (Steuckart, 1974):

Pattern designation	Pattern type
0	Single colour – no pattern
1	Undefined pattern
2	
3	Fabrics with visible yarn structure and/or small patterns
20/0*	Lengthwise stripes; stripe width of 20 mm
010/0	Gentle lengthwise stripes; stripe width of 10 mm
40/40	Checked pattern; repeat size 40 mm × 40 mm
020/020	Gentle checked pattern; repeat size 20 mm × 20 mm

*The first digit with striped and checked patterns denotes pattern dimensions in the warp direction (in mm) and the second dimension in the weft direction.

The orientation of the pattern-pieces depends on the construction of the textile material and its pattern design features. There are three basic types of orientation:

1. Fabrics for which neither the orientation nor the direction is important, for example, random-laid non-woven fabrics;
2. Fabrics for which the orientation is important but the pattern-pieces may be laid in either direction, for example, linings and laminated fabrics; or
3. Fabrics for which orientation and direction are both important, for example, pile fabrics, fabrics with a directional pattern or pile, knitted fabrics.



5.15 Defining repeat dimensions: (a) definitions; (b) example.

To produce garments from fabrics, including pattern repeats, requires proper additional preparation of the pattern-pieces and cutting-markers. This is why it is necessary to define the dimensions of the geometric pattern (or repeat) when preparing a cutting-marker for fabrics with a pattern-repeat.

Pattern-repeat dimensions are defined on the basis of initial repeat dimensions, that is, repeat in the horizontal and vertical directions. It is expressed in mm, whilst a fabric with a pattern-repeat is defined by the dimensions of basic repeat (horizontal and vertical), with its distance from the selvedge[6] or the

[6] **Selvedge** – The edge of a piece of cloth, resp. fabric edge, made strong in such a way that the threads will not come apart.

edge of the fabric (delta A and D), as well as by the dimensions of the auxiliary repeat (delta B, C and E). See Fig. 5.15 (Rogale and Polanović, 1996).

5.6.3 Defining fabric width

Fabric width (i.e. the usable width for which the cutting-marker is planned) should be determined in detail prior to planning the cutting-marker. The maximum width of the cutting-marker is constrained by the usable width of the fabric. The usable width is the width of the narrowest place minus the width of any unusable selvedge (i.e. considered to be the fabric's width with selvedge excluded – the net fabric width). Usable width can be equal to the net width of the smaller, for example, where a technological process causes fabric deformations parallel to the selvedge (i.e. resulting from tensile and thermal stresses in the process of heat-setting), producing unsmooth edges or a slightly wavy selvedge. Where the waves are dissipated towards the centre of the fabric width, usable width is smaller than net width, generally by the width of the deformation, which could seriously harm the clothing's appearance if included in the cutting-marker (Geršak, 1997). When, for example, a jacket's pattern-pieces are cut near the fabric's selvedge, a wavy selvedge causes a significant difference in the fabric, which is reflected as visible transversal stripes on the back part of the jacket – in the seam of the finished article of clothing (see Fig. 5.16, Geršak, 1997).

5.6.4 Fabric dimensional stability

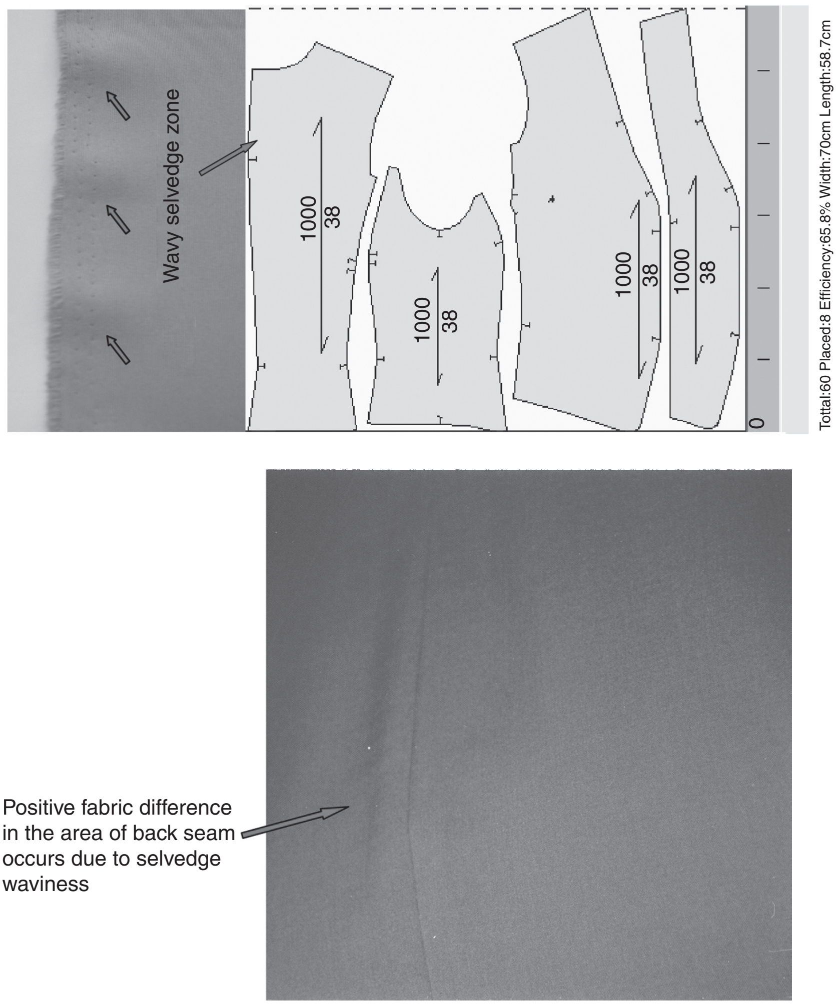
Fabric dimensional[7] stability is one of the most important parameters when defining a cutting-marker. Textile fabrics usually change dimensions in both directions, warpwise and weftwise in woven fabrics, or in the direction of wales and courses in knitted fabrics. It is necessary to establish fabric dimensional stability, that is, shrinkage in both directions, as well as fabric surface shrinkage, which is due to the impact of heat when heat-setting and/or ironing. Surface shrinkage S_{Sur} is an irreversible dimensional change and depends upon warpwise fabric shrinkage by length S_{L} and weftwise or transversal shrinkage S_{Tr}, and can be calculated as follows (Latzke and Hesse, 1974):

$$S_{\mathrm{Sur}} = S_{\mathrm{L}} + S_{\mathrm{Tr}} - \frac{S_{\mathrm{L}} \cdot S_{\mathrm{Tr}}}{100} \qquad [5.1]$$

[7] **Dimensional stability** is fabric dimensional change that occurs when fabrics are exposed to various influences from the environment, that is, heat and/or humidity, or thermal–mechanical and chemical processes in use (Geršak, 2006). Fabrics shrink or elongate by length or width in wet finishing processes when heat, moisture and pressure are applied, as well as in wear and care.

(a)

(b)



5.16 Transversal streaks in the back area of the jacket seam (a and b) as a consequence of deformations, that is, fabric creasing in the selvedge zone.

where:

$$S_L = \frac{l_0 - l_1}{l_0} \times 100 \qquad [5.2]$$

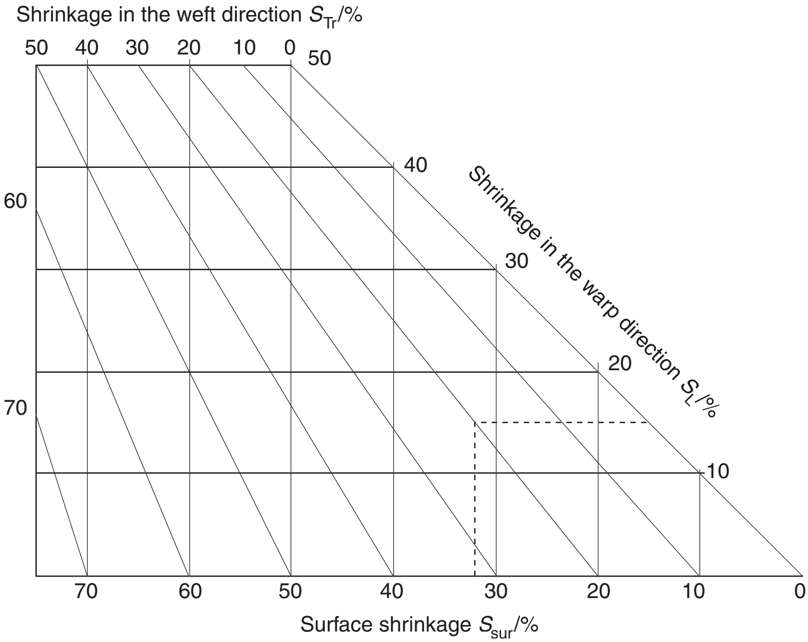
$$S_{Tr} = \frac{w_0 - w_1}{w_0} \times 100 \qquad [5.3]$$

where:

- S_L longitudinal shrinkage, or shrinkage in the direction of the warp, in %,
- S_{Tr} transversal shrinkage or shrinkage in the direction of the weft, in %,
- l_0 the length before thermal treatment, in mm,
- l_1 the length after thermal treatment, in mm,
- w_0 the width before thermal treatment, in mm,
- w_1 the width after thermal treatment, in mm.

When the longitudinal and transversal shrinkages are known, the surface shrinkage can be determined using the nomogram,[8] for example of warp-wise fabric shrinkage S_L = 15% and weftwise shrinkage S_{Tr} = 20%, surface shrinkage S_{Sur} = 32%; see Fig. 5.17 (Latzke and Hesse, 1974).

When the fabric surface shrinkage is known, it is necessary to change the pattern-piece dimensions, as shrinkage when heat-setting and/or ironing



5.17 A nomogram used to determine fabric surface shrinkage.

[8] **Nomogram** [Lat. from Gr. *nómos* nomos; in compounds: law, regulation + -gram from Gr. *grámma, grammatos* letter; in compounds: notation, presentation (anagram, diagram)]; also called a nomograph or alignment chart: a graphical method for exhibiting the value of a function of two independent variables.

could result in dimensional changes of garment pieces, and consecutively in changes in the actual garment size. The differences in dimension can be balanced by adequate changes in pattern-piece dimensions, both in the directions of the warp and the weft, or longitudinal and transversal.

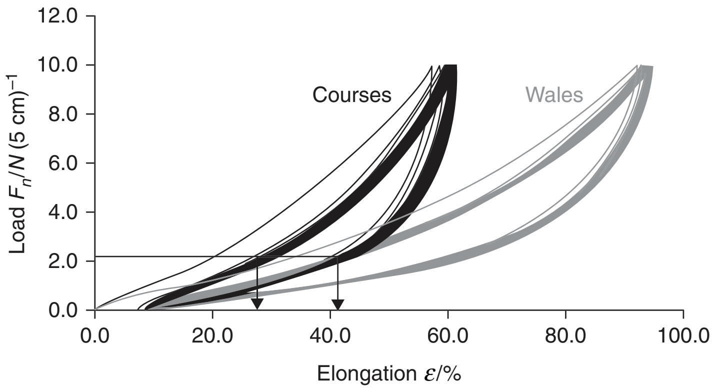
5.6.5 Fabric elasticity

Fabric elasticity[9] is an important parameter, which plays a key role particularly when constructing patterns for tight-fitting garments, in respect of changing pattern-piece sizes for garments such as bathing suits, corsets and wear for cyclists. It is well known that successfully adapting the garment to the contours of a body in motion, and thus to the related dimensional changes of body surface, depends on the type and properties of the fabric used and the garment's construction. To ensure the necessary properties of tight-fitting garments, such as swimsuits and trunks, wear for cyclists, etc. (e.g. balancing comfort with performance), it is necessary to be familiar with the force with which the body acts on the garment and the mechanical response of the materials comprising the garment in question, and the relationship between the two. Adapting an initial pattern of a tight-fitting garment is often done by decreasing the pattern-pieces. The garment pattern-pieces are often, in practice, reduced by subjectively evaluating fabric elasticity, using only a manual elongation test[10].

Objective evaluation of a fabric's mechanical behaviour takes into account its tensile–elastic properties that are exhibited in one-dimensional loading, primarily longitudinal, in the direction of wales, and in the transversal direction, that is, in the direction of the courses. In order to determine a fabric elasticity within this range suitable to offer adequate garment adjustment to body form, the measuring load mentioned above should not significantly exceed the loads occurring during wear. As garments are exposed to repeated loadings during wear, it is advisable to use a tensile test for the multiple loading and the removing of the load at constant measuring load in order to determine the load in wear (based on DIN 53 835 T14: 1981). This

[9] **Elasticity** is the property whereby a body tends to recover its original dimensions, that is, shape and size after a deformation. Elasticity is the degree to which the fabric can be stretched and still be able to return to its original length after the stretching force is removed. A key word in this definition is 'recovery'. Elastic recovery is an important aspect of textile durability. It is necessary for shape retention in both stable and stretch textiles.

[10] **Elongation** is the ability of a textile to extend when subjected to mechanical forces, particularly tensile, shear, bending, and/or compression forces. It is the degree to which the fabric can be strectched without breaking or rupturing the fabric. Elongation is also a component of stretch and plays important roles in body-movement comfort and in shape retention – an aesthetic aspect of textiles.



5.18 Stress–strain diagram at cyclic loads.

test is designed to determine fabric elongation, that is, elastic deformation at cyclic loads, caused by tensile force per unit length.

In order to evaluate elastic properties of a fabric, wearing tests will determine the necessary load to match adequate garment fit with required comfort during wear. Investigations have shown that the feeling of comfort when wearing tight garments is reached at fabric elongation occurring at a load of 1.5 or 2.0 N (5 cm)$^{-1}$ (Krzywinski *et al*., 2002; Dervarič *et al*., 2003). Krzywinski suggests that when constructing patterns for tight-fitting garment models, the so-called 'elasticity factor' be respected (Krzywinski *et al*., 2002; Krzywinski, 2005), which is calculated from the elongation value obtained from a stress–strain diagram $F(\varepsilon)$ at the fifth cycle of loading (Fig. 5.18). Table 5.1 offers the equations necessary for calculating elasticity factors for fabrics that contain elastane fibres.[11]

The calculated values for a fabric's elasticity factor are included in the rules of construction in the form of x-values, which enable quick and flexible fabric parameter changes (Krzywinski *et al*., 2002). As some garment pieces require lower values of fabric elasticity (i.e. shoulders, armholes, etc.), the so-called reduced elasticity factor is used for these pattern-pieces.

Changes to pattern-pieces in respect of the requirements for tight-fitting models can also be determined through the knowledge of the fabric elastic

[11] **Elastane fibres** are synthetic fibres composed of linear macromolecules. They contain not less than 85% of segmented polyurethane, which is in turn composed of aliphatic polyesthers, or polyethers (soft range) and polyurethane segments (hard range). Soft ranges compose long, non-oriented flexible chains, which give high elongation properties to the elastane fibre (Gries, 2005). Elastane filaments possess high elongation, between 300% and 700%, and excellent elastic return. From the construction point of view, they can be wrapped yarns, core-spun yarns, air-entangled or core-twist yarns. Fabrics including elastane are characterised by high elongation and elasticity (Gries, 2005).

Table 5.1 Equations to calculate elasticity factors for fabrics containing elastane

Elongation in % at the load of 2 N/5 cm	Elasticity factor			
	Longitudinal		Transversal	
From 0 to 15	$f_L = \frac{1}{1+\varepsilon_l}$	[5.4]	$f_{Tr} = \frac{1}{1+\varepsilon_{Tr}}$	[5.8]
From 16 to 30	$f_L = \frac{1}{1+(\varepsilon_1/2)}$	[5.5]		
From 31 to 40	$f_L = \frac{1}{1+(\varepsilon_1/3)}$	[5.6]		
Above 40	$f_L = \frac{1}{1+(\varepsilon_1/4)}$	[5.7]		
Reduced elasticity factor	$f_{L-red} = \frac{1}{1+(\varepsilon_1/2)}$	[5.9]	$f_{Tr-red} = \frac{1}{1+(\varepsilon_{Tr}/2)}$	[5.10]

recovery value e_w, as a ratio of the recovered (i.e. elastic deformation) ε_e and total deformation ε_t expressed as (Morton and Hearle, 1993; Geršak, 2006):

$$e_w = \frac{\varepsilon_e}{\varepsilon_t} \qquad [5.11]$$

The appropriate elasticity factor f_e should be determined when taking into account modifications to the pattern-pieces, both longitudinally and transversal, as they relate to the value for elastic recovery. Such an elasticity factor ensures proper adaptation of the model to the required comfort during wear and does not allow excess elongation of the material used for a particular article of clothing (e.g. the material in a bathing suit in a wet state stretches due to the mass of water absorbed).

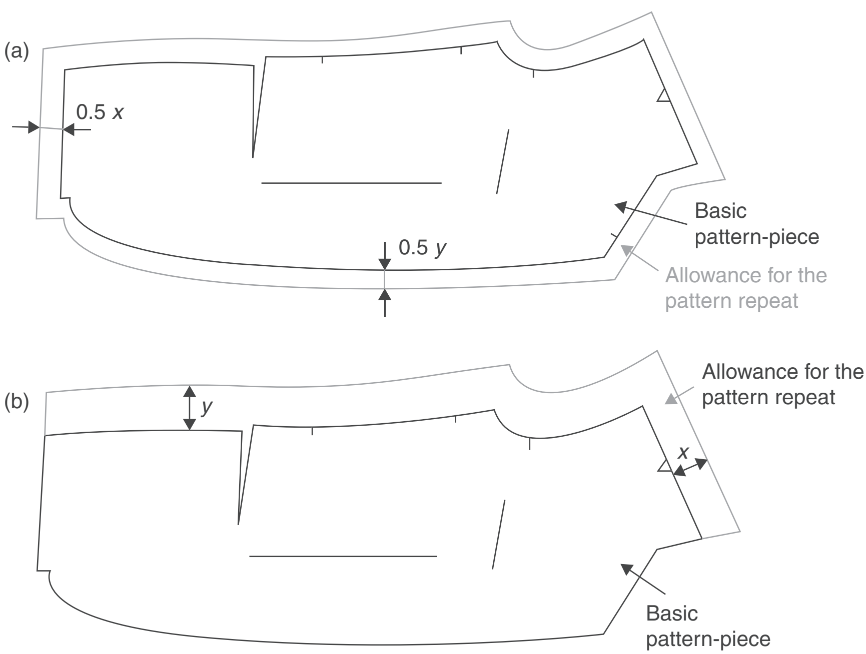
5.6.6 Positions of pattern-pieces within a cutting-marker

The positions of the pattern-pieces within a cutting-marker play an important role, when regarding the quality of the finished garment as a whole. This is why it is necessary to precisely define the positions of the pattern-pieces in a cutting-marker, during the process of defining cutting-marker parameters. The positions depend upon:

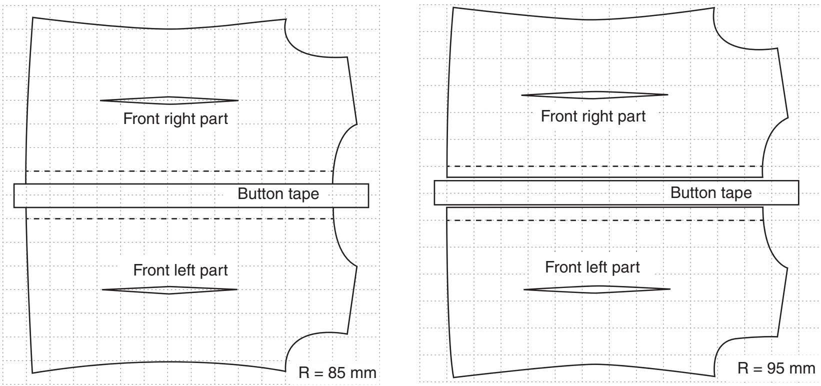
- fabric surface structure;
- pattern or repeat type and the desired result in the finished garment; and
- cutting requirements, that is, manner of cutting-lays into garment pieces.

Fabric surface structure and texture have an impact on the positions of the pattern-pieces within a cutting-marker. The pattern-pieces normally carry a grain line. The grain line generally should lie parallel to the line of the warp in a woven fabric or the wales in a knitted fabric. Many fabrics can be turned around (through 180°) and retain the same appearance, and these are designated as 'either-way' or 'symmetrical'. They require no special action on the part of the cutting-marker planner. More restricting are fabrics known as 'one-way – either-way' or 'asymmetrical'. In this case, if a ply of fabric is turned around it does not retain the same appearance, especially when two pattern-pieces with opposite ways are sewn together. This requires special cutting-marker planning and means that all pattern-pieces of an individual garment should lie in the same direction. Examples of such fabrics are those with a nap or pile that is brushed in one direction and whose surface reflects the light differently, knitted fabrics where the loops of the wales always point in the same direction, and fabrics with an asymmetrical surface structure that does not run the same way, all of which require one-direction positioning only.

As mentioned earlier, the position of pattern-pieces in a cutting-marker are also limited by fabric pattern or repeat – see Fig. 5.7. In order to ensure



5.19 Correction allowance for the pattern-repeat on pattern-piece contours. (a) Symmetrical or centred allowance and (b) asymmetrical allowance.



5.20 Pattern-piece position as related to pattern-repeat size.

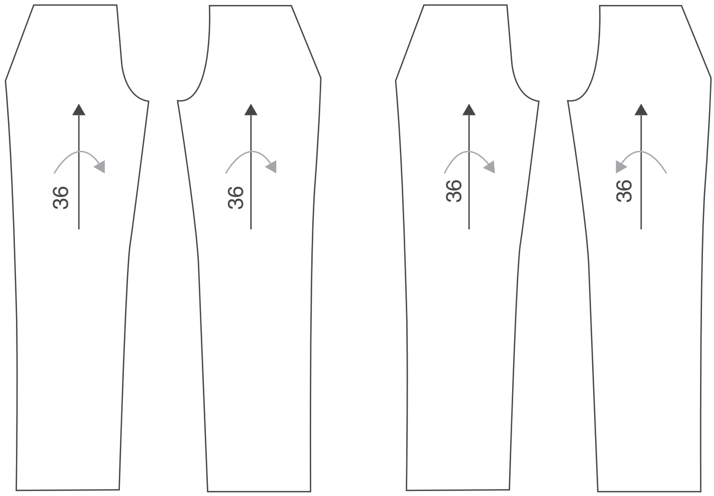
precise pattern-repeat matching in the finished garment, a length of fabric is usually added, known as a correction allowance, which enables the necessary shift of pattern-pieces to match the fabric pattern precisely. This allowance to the pattern-piece's contours can be symmetrical (centred) or asymmetrical, as shown in Fig. 5.19. Its size depends upon the size of pattern-repeat; Fig. 5.20.

The positions of the pattern-pieces in a cutting-marker are also defined by the requirements of the cutting process, taking into account the direction of the contour of the pattern-piece. To ensure precise cutting, the direction of cutting and the movement of the cutting-head must be optimised. Two basic rules should be obeyed to prevent vacuum losses:

1. The primary rule is that the cut part should be removed from the left to the right side.
2. The secondary rule is that the smaller part should be removed first.

Cutting quality is, to a great extent, dependent on the efficaciousness of the vacuum applied on the cutting-lay. Smaller parts are cut first (which ensures the cutting-lay fixes properly to the nylon bristles which support the fabric lay), and the bigger parts are cut later. Cutting is performed in a clockwise direction, so all the pattern-pieces are cut in the same direction – see Fig. 5.21a. When the cutting-plies are laid the same way up, deformations of the garment pieces can occur, due to the force the knife blade exerts on the layers (particularly in the case of elastic fabrics and fabrics of low air permeability, as this reduces the efficaciousness of the vacuum, which means the lays are not properly fixed).

Deformations occur as control-incisions shift on the parts cut. For example, on a pair of trousers, the beginning of the right front-leg part cut is in the area



5.21 Co-directional and symmetrical cut of the left and right parts: (left) clockwise cut; (right) symmetrical cut.

of the upper part of the side seam. The forces exerted by the knife blade can move the knee control incision by as much as 2 mm. Contrary to this, the beginning of the left front-leg cut, which is also cut clockwise, is in the upper seat. The knee control incision can again shift by 2 mm, but in the opposite direction to that of the right leg. This means that the departure of control incisions from where they should be to where they end up is 4 mm, which is quite unacceptable from a quality point of view. These technology-caused deformations often require an optimisation of the cut at the left and right parts of the garment; see Fig. 5.21b. The distances between the individual pattern-pieces in a cutting-marker should be determined, having in mind their positions, fabric type, and the technological requirements and conditions of cutting.

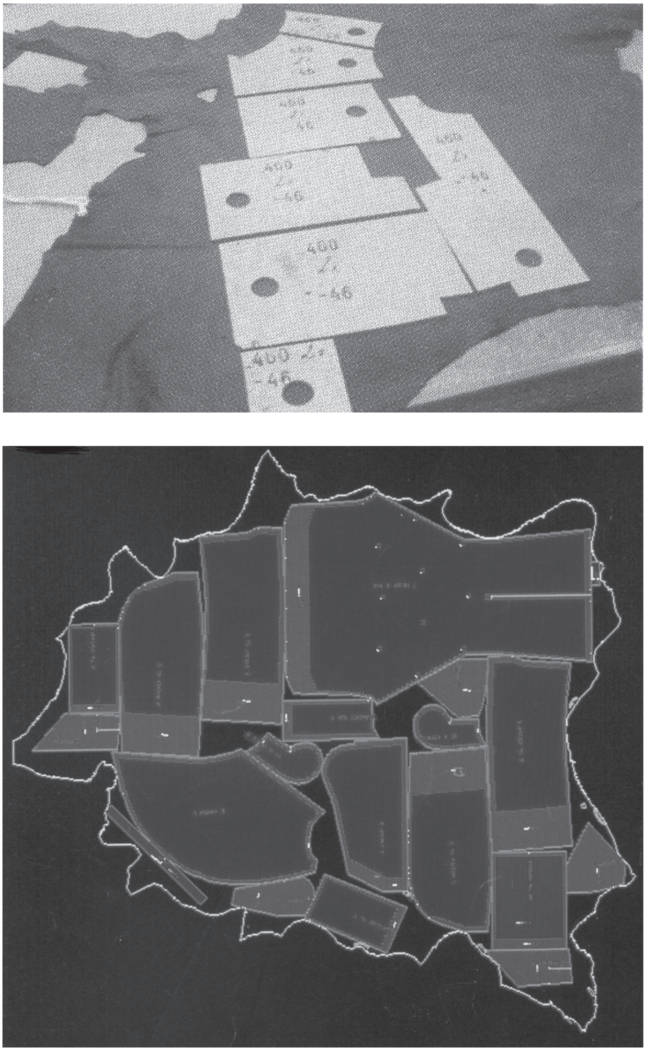
5.7 Technological requirements when arranging pattern-pieces within a cutting-marker

Cutting-marker planning is a conceptual, intuitive, open and creative process. Pattern-pieces are arranged in a cutting-marker with regard to a predetermined fabric width (or, if leather is concerned, with regard to the surface of a particular leather, Fig. 5.22), whilst cutting-marker length depends on the combination of single or multiple garment sizes in the cutting-marker.

It is generally true that the pattern-piece's position in a cutting-marker is defined in relation to the groups of fabrics, which differ by:

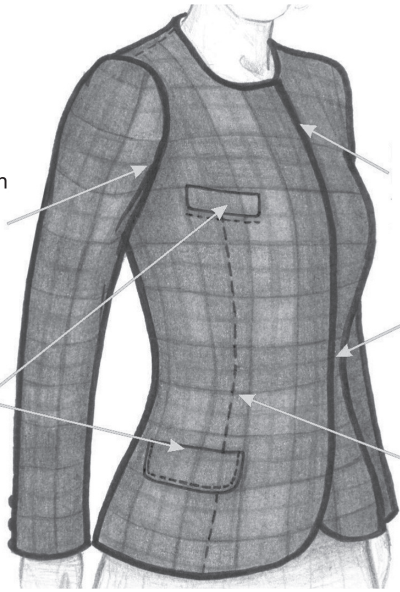
- the type of pattern (plain colour, striped, checked); and
- their orientation (with respect to surface nap, asymmetric surface texture).

(a) (b)



5.22 Position of pattern-pieces in the case of a cutting-marker on leather (a and b).

From the point of view of technological requirements, pattern-pieces are arranged in a cutting-marker in the direction of the warp yarns (woven) or courses (knitted). Exceptions are made when special effects are sought regarding the structure and type of fabric pattern (fabrics with pattern repeats, with checked patterns, and striped fabrics). This is why particular pattern-pieces are laid at a specific angle in relation to the warp yarns, which for checked fabrics is 45°, and for striped fabrics 90°.



5.23 Quality requirements for matching pattern-repeat.

To determine and fulfil the quality requirements of a particular model, it is also necessary to ensure pattern matching, especially in the areas of:

- the back part of the collar;
- the front-part of the sleeves; and
- pockets, etc.

Features of accurate pattern matching (Eberle *et al.*, 1993, 2002) include:

- symmetry: the pattern must be symmetrical around the central axis (e.g., left and right front panels, collars and backs);
- vertical continuity: the pattern must not be interrupted or displaced at horizontal seams (e.g., pockets);
- vertical continuity: the pattern must not be interrupted or displaced at vertical seams or across adjacent parts (e.g., arm and front panel); and
- overall continuity: the form and repeat of the pattern must be maintained across all seams, facings, trimmings, patches, etc.

Quality requirements regarding pattern matching, using the example of a woman's dress, can be seen in Fig. 5.23.

5.8 Cutting-marker efficiency

When arranging pattern-pieces into a cutting-marker its degree of utilisation should be considered, to avoid the considerable fabric losses that occur when arranging pattern-pieces. These cannot be completely eliminated, but can be reduced by optimising the cutting-marker. All the elements that compose a cutting-marker should be precisely defined in order to analyse cutting-marker utilisation, as well as the elements present when cutting lays into garment parts.

The elements that define the cutting-marker's degree of utilisation are:

- the cutting-marker's net surface, that is, the surfaces of all the pattern-pieces of single or multiple models, arranged in the cutting-marker;
- the cutting-marker's gross surface, that is, the surface upon which all the pattern-pieces of single or multiple models are arranged; and
- intercutting losses, representing the waste generated by placing the pattern-pieces into a cutting-marker; in effect, the difference between the gross and net surface of the cutting-marker.

Cutting-marker utilisation can be calculated using the following expression:

$$I_{\text{c-mar}} = \frac{A_N}{A_G} \times 100 \qquad [5.12]$$

where:

$$A_G = L_{\text{c-mar}} \cdot w_{\text{c-mar}} \qquad [5.13]$$

whilst intercutting losses are calculated as follows:

$$I_{\text{IL}} = \frac{A_G - A_N}{A_G} \times 100 \qquad [5.14]$$

where:

$I_{\text{c-mar}}$ – cutting-marker utilisation, in %,
A_N – cutting-marker net surface, in cm^2,
A_G – cutting-marker gross surface, in cm^2,
I_{IL} – intercutting losses, in %,
$L_{\text{c-mar}}$ – cutting-marker length, in cm,
$w_{\text{c-mar}}$ – cutting-marker width, in cm.

Cutting-marker utilisation has a considerable impact on the materials' costs, which are a component of manufacturing, and are of key importance in materials management. Cutting-marker utilisation depends on the following main elements:

- model type and shape;
- garment size;
- fabric type (plain colour, fabrics with oriented surface structure, fabrics with pattern-repeat, symmetric or asymmetric, pattern-repeat size);
- fabric width; and
- cutting-marker type (whole, half, single-size, multi-size).

5.8.1 The impact of model type and shape on cutting-marker utilisation

Cutting-marker utilisation is directly influenced by model type and shape, as well as by the structures of the associated pattern-pieces. Generally, products can be divided into three broad categories (Tyler, 1991):

1. Relatively simple products or models;
2. Products with a large number of small parts; and
3. Products with relatively large parts that fit in multiples across the width.

The category of relatively simple products or models includes towels, set covers for furniture and cars, as well as some other similar products with rectangular pattern-pieces. Cutting-marker utilisation for such products approaches 100%. As pattern-pieces are rectangular, or nearly so, a growing number of pattern-pieces, for example, two or three units, does not mean a higher degree of cutting-marker utilisation. Utilisation remains approximately the same, as the number of possible combinations in the pattern-pieces arrangement does not change with an increased number of pieces (Tyler, 1991).

The category of products with a large number of small parts includes men's suits, shirts, and some blouses. Cutting-marker utilisation increases with an increased number of pattern-pieces because the numerous small pieces offer, with an increased number of garments or garment sizes, more options for their arrangement in the cutting-marker.

The category of products with relatively large parts includes men's and women's trousers, some dresses, sweatshirts, and similar products. These products are characterised by large parts, which correspond to multiple fabric widths, or a multi-size cutting-marker. The large rectangular pieces demand the whole fabric width, whilst smaller ones are arranged in the 'waste' spaces generated when placing the larger pieces. As the number of small pieces is limited, the cutting-marker is determined by fabric width, and the

Table 5.2 Cutting-marker utilisation depending on model type and garment size (example for trousers)

Designation		Cutting-marker				Pattern-pieces number	Fabric required per unit L_m/cm
Model	Cutting-marker	Width $w_{c\text{-}mar}$/cm	Garment size combination	Length $L_{c\text{-}mar}$/cm	Utilisation $I_{c\text{-}mar}$/%		
M01	CM01	150	38 + 40	180	81.55	14	179
	CM02		36 + 42	180	81.75	14	
	CM03		34 + 38	177	78.27	14	
M02	CM04	150	38 + 40	230	73.35	7	231
	CM05		36 + 42	235	71.84	7	
	CM06		34 + 38	228	69.46	7	

Table 5.3 Cutting-marker utilisation depending on fabric width (in the case of trousers)

Cutting-marker				
Designation	Width $w_{c\text{-}mar}$/cm	Garment size combination	Length $L_{c\text{-}mar}$/cm	Utilisation $I_{c\text{-}mar}$/%
CM01	147	50 + 52	143	80.65
CM02	148	50 + 52	140	81.81
CM03	149	50 + 52	137	82.84
CM04	150	50 + 52	135	83.77

number of garments or garment sizes within the evaluated cutting-marker. Optimal cutting-marker utilisation for this category of products can be primarily achieved by trying various combinations in practice, as the utilisation depends on the fabric, respective of the cutting-marker width and the number of garments or garment sizes.

5.8.2 The impact of garment size and fabric width on cutting-marker utilisation

Cutting-marker utilisation is directly impacted by garment size and the combination of garment sizes within the cutting-marker, the structure of associated pattern-pieces, as well as fabric width. Cutting-marker utilisation, as a function when combining garment sizes for two different trouser models, is shown in Table 5.2, whilst the impact of fabric width on cutting-marker utilisation can be seen in Table 5.3. The results show that a higher fabric width results in better cutting-marker utilisation and the tests indicate that the best cutting-marker utilisation for trousers is achieved with a fabric width of

Table 5.4 Cutting-marker utilisation as related to the type of garment size and the method of arranging pattern-pieces into the cutting-marker

Cutting-marker					Fabric consumption per unit L_m/cm	Methods of arranging pattern-pieces
Designation	Width $w_{c\text{-}mar}$/cm	Garment size combination	Length $L_{c\text{-}mar}$/cm	Utilisation $I_{c\text{-}mar}$/%		
CM01	148	50 + 52 54 + 56 58 + 60	492	76.41	165	Unidirectional pattern-piece arrangement
CM02		100 + 104 108 + 112 116 + 120	514	76.20	172	
CM03	148	50 + 52 54 + 56 58 + 60	448	83.90	150	Bidirectional pattern-piece arrangement
CM04		100 + 104 108 + 112 116 + 120	464	84.27	156	

150 cm. Optimal fabric width depends upon the garment type, model type, and pattern-pieces structure, and can be determined primarily by trials.

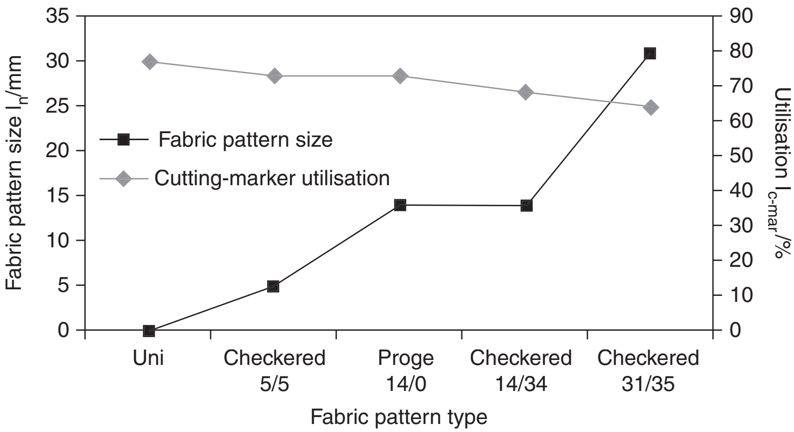
5.8.3 The impact of the fabric type and pattern size on cutting-marker utilisation

The type of fabric used also plays an important role when arranging pattern-pieces into a cutting-marker. Having in mind the technological requirements when arranging pattern-pieces, the best cutting-marker utilisation is achieved with single-colour fabrics, followed by fabrics with an oriented surface structure, which require pattern-pieces to be arranged in one direction. Table 5.4 shows the impact of different methods for arranging pattern-pieces, that is, in single and two directions for various combinations of garment sizes, on the degree of cutting-marker utilisation (using an example of trousers).

Cutting-marker utilisation depends on the type of model and the possibilities of including pattern-pieces in the cutting-marker. The type of fabric pattern and pattern-repeat size directly impact the degree of cutting-marker utilisation. Asymmetrical patterns require pattern-pieces to be arranged in one direction, which additionally impacts cutting-marker utilisation. The degree of utilisation depends on the type of fabric pattern (single-coloured, striped, checked) and pattern-repeat size, and can be seen in Table 5.5 and Fig. 5.24, which also shows that cutting-marker utilisation decreases with an increasing pattern-repeat size.

Table 5.5 Cutting-marker utilisation depending on the type of fabric pattern and pattern-repeat size

Cutting pattern designation	Fabric pattern type	Pattern-repeat size		Cutting-marker utilisation
		Horizontal l_h/mm	Vertical l_v/mm	$l_{c\text{-}mar}$/%
CM01	Plain colour	0	0	77.37
CM02	Striped	14	0	73.38
CM05	Checked	5	5	72.93
CM04	Checked	14	34	68.48
CM03	Checked	31	35	64.15



5.24 Cutting-marker utilisation depending on pattern type and fabric pattern horizontal size.

5.8.4 The impact of cutting-marker type on its utilisation degree

Besides model type, fabric width, fabric pattern and pattern-repeat size, the degree of cutting-marker utilisation is, to a considerable extent, influenced by the optimal composition of the cutting-marker, as determined through its structure (whole or half) and defined by the combination of garment sizes. Obviously, absolute values cannot be known in advance, but they can be precisely determined for particular types of garment models. It should be clear in advance the number of garment size units that can and cannot be advantageous.

Practical experience says that two units of the same or different garment sizes offer better utilisation than three, four better than two, five worse than four, six better than four, etc. It should be noted that optimising is possible for every garment type and differs significantly from one example to

Table 5.6 Utilisation of single-size and multi-size cutting-marker for a man's shirt

Cutting-marker					Average fabric consumption per unit L_m/cm
Designation	Width $w_{c\text{-}mar}$/cm	Garment size combination	Length $L_{c\text{-}mar}$/cm	Utilisation $I_{c\text{-}mar}$/%	
CM01	88	42	238	83	238
CM02	88	42 x 2	449	88	225
CM03	88	42 x 4	875	90	219

Table 5.7 Utilisation of single-size and multi-size cutting-marker for a woman's coat

Cutting-marker					Average fabric consumption per unit L_m/cm
Designation	Width $w_{c\text{-}mar}$/cm	Garment sizes combination	Length $L_{c\text{-}mar}$/cm	Utilisation $I_{c\text{-}mar}$/%	
CM01	148	38	283	70	283
CM02	148	44	305	70	305
CM03	148	38 + 44	504	81	252

another. An example of utilisation for a single-size and multi-size (equal size) cutting-marker for a man's shirt can be seen in Table 5.6, whilst a woman's coat, as an example of the same size, is represented in Table 5.7.

5.9 Fabric losses outside the cutting-marker

Although fabric consumption is more or less determined by the cutting-marker, the losses outside the cutting-marker are highly important from the point of view of materials management. They are associated with fabric spreading[12] into cutting-lays, and can be divided into (Tyler, 1991):

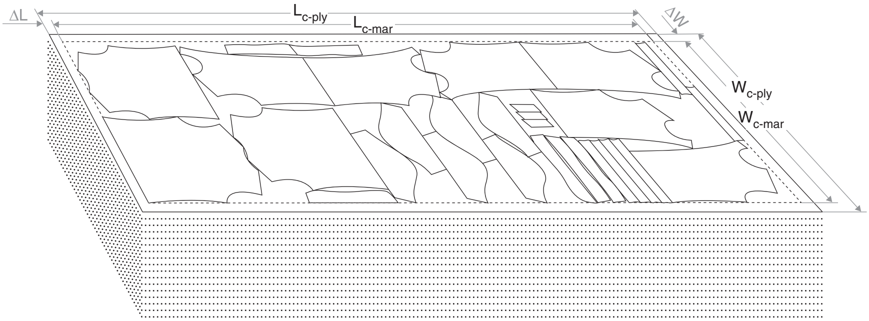
- direct fabric losses; and
- indirect fabric losses.

5.9.1 Analysis of direct fabric losses

Direct fabric losses include:

- losses at the ends of the cutting-ply;
- losses along the cutting-ply length;

[12] **Spreading** – means the smooth laying out of the fabric in superimposed layers (plies) of specified length.



5.25 Fabric losses outside the cutting-marker.

- end of piece losses; and
- splicing losses and fabric faults.

Losses at the ends of cutting-plies (ΔL) are those losses that appear as fabric allowances at the ends of each ply. These losses are illustrated in Fig. 5.25.

The necessary fabric allowance, as a result of fabric instability and the elastic properties of the woven or knitted fabrics used, is between 10 and 20 mm at each end of the cutting-ply, or 20–40 mm per cutting-ply. Some stable fabrics may permit smaller allowances and some unstable fabrics may require more. This kind of fabric loss at each end of the cutting-ply represents 0.25–0.5% for a cutting-lay of 8 m, whilst for a cutting-lay 4 m in length the losses are between 0.5% and 1.0%. Allowance size depends upon the fabric type and its properties. Table 5.8 shows an example of the percentage allowance at each end of the cutting-plies for five analysed work orders, during the manufacture of knitted garments.

Losses along cutting-ply length (Δw_{loss}) are the losses that occur due to the difference between actual and usable fabric widths. The starting point for determining cutting-marker width should always be the usable fabric width. It depends on selvedge quality, fabric width stability, and adequate material control when spreading, for example, correct alignment of the selvedge. The cutting-marker is usually 2–3 cm narrower than the actual fabric width, meaning it equals the fabric width without selvedge. This is true, provided the fabric width without selvedge is the same as its usable width. Table 5.9 offers a review of the percentage loss along the cutting-plies for five analysed work orders concerning knitted garments.

Losses due to fabric remaining in the roll, for example, end of piece losses, concern the fabric remaining in the rolls after laying it into cutting-lays. This type of loss can vary significantly, because the fabric length is generally not an exact multiple of the cutting-ply length. If cutting-markers are rather short, and the fabric rolls rather long, the percentage loss is usually insignificant. For example, if a blouse is cut with a cutting-marker 150 cm long from a roll

Table 5.8 A review of losses as fabric allowances at the each end of cutting-plies for the analysed orders of knitted garments

Designation		Cutting-marker			Cutting-lay	
Work-order	Model	Designation	Garment size combination	Length $L_{c\text{-}mar}$/cm	Length $L_{c\text{-}lay}$/cm	Loss percentage ΔL_{loss}/%
D1	M01	CM01–1	52, 54, 56	735	740	0.68
D2	M02	CM02–2	50, 52, 54, 56, 58	605	610	0.83
		CM02–3	50, 52, 54, 56	464	469	1.08
D3	M03	CM03–4	52, 54, 56	697	702	0.72
		CM03–5	50, 58	484	489	1.03
D4	M04	CM04–6	102, 126, 162	430	435	1.16
		CM04–7	114, 138, 150, 156	774	779	0.64
D5	M05	CM05–8	114, 138, 162	417	422	1.19
		CM05–9	102, 126, 150, 156	459	464	1.09

Table 5.9 A review of the percentage fabric loss along the cutting-plies, for five analysed work orders concerning knitted garments

Work-order	Model name	Cutting-market			Cutting-lay	
		Designation	Garment size combination	Width $w_{c\text{-}mar}$/cm	Width $w_{c\text{-}mar}$/cm	Loss percentage Δw_{loss}/%
D1	M01	CM01–1	52, 54, 56	147	153	5.08
D2	M02	CM02–2	50, 52, 54, 56, 58	191	204	6.81
		CM02–3	50, 52, 54, 56	191	204	6.81
D3	M03	CM03–4	52, 54, 56	156	160	2.56
		CM03–5	50, 58	156	160	2.56
D4	M04	CM 4–6	102, 126, 162	140	145	3.57
		CM04–7	114, 138, 150, 156	140	145	3.57
D5	M05	CM05–8	114, 138, 162	140	145	3.57
		CM05–9	102, 126, 150, 156	140	145	3.57

of 120 m, the fabric loss remaining in the roll will be less than 75 cm, which is below 0.6%. However, if a garment is cut with a cutting-marker length of 270 cm from a roll of 45 m, some 135 cm of the fabric will remain in the roll, which is as much as 3%. Losses can be reduced through optimisation. However, optimisation when cutting and minimising the fabric remaining on the roll does not make much sense if a fabric with mistakes is processed or if the differences in length among the individual rolls are considerable.

5.9.2 Analysis of indirect fabric losses

Indirect fabric losses include:

- losses due to fabric remaining in rolls as a result of creases or some other fabric deformations in the roll;

- losses occurring during cutting-marker making; and
- losses due to differences in fabric roll-length.

5.10 Determining fabric consumption

When the cutting-marker elements are known, as well as the direct and indirect fabric losses outside the cutting-marker (fabric losses when cutting), the fabric consumption can then be calculated for a particular cutting-ply:

$$L_m = L_{\text{c-ply}} = L_{\text{c-mar}} \cdot k_{\text{loss}} + \Delta L \qquad [5.15]$$

or for a cutting-lay:

$$L_{m\text{c-lay}} = n \cdot L_{\text{c-ply}} = n \cdot \left(L_{\text{c-mar}} \cdot k_{\text{loss}} + \Delta L\right) \qquad [5.16]$$

where:

- L_m theoretical fabric consumption, in cm,
- $L_{\text{c-ply}}$ cutting-ply length, in cm,
- $L_{\text{c-mar}}$ cutting-marker length, in cm,
- ΔL losses at the ends of cutting-ply, in cm (see Fig. 5.25),
- k_{loss} coefficient expressing fabric losses when cutting,
- n number of cutting-plies in cutting-lay,
- $L_{m\text{c-lay}}$ fabric length in the cutting-lay, in cm.

The coefficient k_{loss}, describing fabric losses when cutting, can be calculated as follows:

$$k_{\text{loss}} = k_{\text{re}} + k_{\text{fa}} + k_{\text{de}} \qquad [5.17]$$

where:

- k_{re} coefficient describing fabric loss due to the fabric remaining on the roll, in %,
- k_{fa} coefficient describing fabric loss due to overlapping cutting-plies with a fault, or due additional cutting parts with a fault in/on the fabric, in %,
- k_{de} coefficient describing fabric loss due to additional cutting of damaged or destroyed garment parts, in %.

The total fabric consumption for a work-order is determined regarding the cutting-lays structure, using the following expression:

$$L_{m_{\text{tot}}} = L_{m\text{c-lay}_1} + L_{m\text{c-lay}_2} + \cdots + L_{m\text{c-lay}_N} = \sum_{i=1}^{N} L_{m\text{c-lay}_i} \qquad [5.18]$$

or having in mind the number of garment sizes in a particular cutting-lay:

$$L_{m_{\text{tot}}} = \left(L_{\text{c-mar}1} \cdot f_{\text{c-mar}1} \cdot K_1 + L_{\text{c-mar}2} \cdot f_{\text{c-mar}2} \cdot K_2 + \dots + L_{\text{c-marN}} \cdot f_{\text{c-marN}} \cdot K_{\text{N}}\right) \cdot k_{\text{loss}} + n_{cp} \cdot \Delta L \quad [5.19]$$

where $f_{\text{c-mar}}$ is the factor of cutting-marker structure, relating to the number of garment sizes in the cutting-marker, calculated as:

$$f_{\text{c-mar}} = \frac{1}{n_{\text{os}}} \quad [5.20]$$

whilst the average fabric consumption for an article of clothing can be calculated using the following expression:

$$\bar{L}_m = \frac{\left(L_{\text{c-mar}1} \cdot f_{\text{c-mar}1} \cdot K_1 + L_{\text{c-mar}2} \cdot f_{\text{c-mar}2} \cdot K_2 + \cdots + L_{\text{c-marN}} \cdot f_{\text{c-marN}} \cdot K_N\right) \cdot k_{\text{loss}} + n_{cp} \cdot \Delta L}{K_{N_{\text{tot}}}} \quad [5.21]$$

where:

$\bar{L}_m$	average fabric consumption for the article of clothing, in cm
$L_{mc\text{-lay}_i}$	fabric length in the ith cutting-lay ($i = 1, 2, 3, \dots, N$), in cm,
$K_{N\text{tot}}$	total number of garments in the work-order, as pieces,
N	total number of cutting-lays,
n_{cp}	total number of cutting-plies,
ΔL	losses at the ends of cutting-ply, in cm,
k_{loss}	coefficient describing fabric losses when cutting,
$f_{\text{c-marN}}$	factor describing cutting pattern structure,
n_{os}	the number of garment sizes in the cutting-marker, as pieces,
$K_1, K_2, \dots, K_N$	the number of articles of clothing in the cutting-lay, as pieces.

Fabric loss occurring as an allowance, ΔL, at the initial and end parts of a cutting pattern, depend on the fabric type and its properties, and are determined according to fabric stability, whilst the coefficient k_{loss}, which describes fabric loss when cutting is determined, is based on the statistical analysis of actual fabric losses during cutting-processes.

5.11 Conclusions

Clothing-design analysis and activities planning with regard to constructing garment patterns, pattern making and cutting is, in effect, that part of production planning that connects design to production by defining all the components, such as fabric, lining and interlining, that have to be cut for a piece of clothing, within specified parameters. It is a key element in the organisation of preproduction activities of clothing manufacture. Apart from defining and directing preproduction activities, clothing-design analysis is involved in the engineering work and optimisation required, and is one of the preconditions for assuring the efficiency and stability of the basic product manufactured.

This aspect of production planning defines how the task – the new product – will be done and under what conditions (i.e., the technical criteria). However, we cannot ignore the quality assurance function, which attempts to ensure that the product scope, cost, and time function are fully integrated into the complete process of clothing-design analysis and activities planning, and this will be addressed in a later chapter.

5.12 References

Aldrich, W. (2002), *Pattern Cutting for Women's Tailored Jackets: Classic and Contemporary,* First published, Oxford, Blackwell Science Ltd.

Aldrich, W. (2004), *Metric Pattern Cutting*, Fourth Edition, Oxford, Blackwell Publishing Ltd.

Dervarič, R., Krzywinski, S. and Geršak, J. (2003), 3D construction of cyclist wear and manufacture of prototype. Proceedings of the 4th International Conference *Innovation and Modelling of Clothing Engineering Processes* IMCEP 2003, October 9–11, 2003, Maribor, University of Maribor, Faculty of Mechanical Engineering, Institute for Textile and Garment Manufacture Processes, 215–221.

DIN 53 835 T14 (1981), Prüfung des zugelastischen Verhaltens, August 1981.

Eberle, H., Hermeling, H., Hornberger, M., Menzer, D. and Ring, W. (1993), *Fachwissen Bekleidung*, 3. Auflage, Haan-Gruiten, Verlag Europa-Lehrmittel, Nourney, Vollmer GmbH & Co.

Eberle, H., Hermeling, H., Hornberger, M., Kilgus, R., Menzer, D. and Ring, W. (2002), *Clothing Technology*, Third English Edition, Haan-Gruiten, Verlag Europa-Lehrmittel, Nourney, Vollmer GmbH & Co.

Geršak, J. (1997), *A Professional Opining on the Causes of Fabric and Jacket Deformations* (in Slovenian), Maribor, Faculty of Mechanical Engineering.

Geršak, J. (2006), *Mechanical and Physical Properties of Textile Materials*, Maribor, University of Maribor, Faculty of Mechanical Engineering.

Gries, T. (2005), *Elastische Textilien, Garne, Verarbeitung, Anwendung*, Frankfurt am Main, Deutscher Fachverlag GmbH.

Knez, B. (1994), *Construction Preparation in Garment Industry* (in Croatian), Zagreb, Faculty of Textile Technology, University of Zagreb.

Krzywinski, S., Tran Thi, N. and Rödel, H. (2002), Schnittgestaltung für körpernahe Bekleidung aus Maschenwaren mit Elastangarnen, *Maschen-Industrie*, **6**, 36–39.

Krzywinski, S. (2005), *Verbindung von Design und Konstruktion in der textilen Konfektion unter Anwendung von CAE*, Habilitationsschrift, Dresden, TU Dresden, Verlag der Wissenschaften GmbH.

Latzke, P. M. and Hesse, R. (1974), *Textilien, Prüfen – Untersuchen – Auswerten*, Berlin, Fachverlag Schiele and Schön GmbH.

Morton, W. E. and Hearle, J. W. S. (1993), *Physical Properties of Textile Fibres*, Third Edition, Manchester, The Textile Institute Manchester.

Rogale, D. and Polanović, S. (1996), *Computerised System of Construction Preparation in Garment Industry* (in Croatian), Zagreb, University of Zagreb, Faculty of Textile Technology.

Schierbaum, W. (1993), *Bekleidungs-Lexikon*, 3. erweiterte Auflage, Berlin, Fachverlag Schiele and Schön GmbH.

Steuckart, H. (1974), *Untersuchung von Vergleichskriterien für die Optimierung von Zuschneideverfahren*, Opladen, Westdeutscher Verlag GmbH.

Tyler, D. J. (1991), *Materials Management in Clothing Production*, Oxford, London, Edinburgh, BSP Professional books.

Ujević, D., Rogale, D. and Hrastinski, M. (2000), *Garment Constructing and Modelling Techniques* (in Croatian), Zagreb, University of Zagreb, Faculty of Textile Technology.

6
Planning clothing manufacturing

DOI: 10.1533/9780857097835.145

Abstract: This chapter analyses clothing manufacture, work methods, and planning, linking construction, engineering and technology. The chapter begins with the general requirements of planning clothing manufacturing, and analysis of clothing manufacture, selecting appropriate processing equipment in view of the characteristics of sewing machines, work methods, and elements composing the standard time it takes to perform a task. Against this background, the planning of manufacturing activities is explained, including the sewing-operation plan, planning clothing assembly, and process system. Finally, planning clothing manufacturing processes that play an important role during process management are discussed.

Key words: clothing manufacturing, planning, work analysis, work methods, sewing stitch, sewing seam, sewing machines, welding techniques, standard time, sewing-operation plan, manufacturing process systems, sewing process plan.

6.1 Introduction

In Chapter 4 we described the role and functions of clothing production planning, and defined the necessary technical key documentation and quality requirements for manufacturing. Chapter 5 introduced the first stage of clothing production planning, including garment pattern construction, grading, preparing cutting-markers and determining material consumption. In this chapter we will look at clothing manufacturing planning, which includes analysis of clothing manufacture and selection of appropriate equipment, work methods, types of sewing machines in terms of their technical characteristics, determining standard time when planning manufacturing operations, and clothing manufacturing processes.

Clothing manufacturing activities planning occupies – as a link to construction, engineering and technology – a central position in the manufacturing process. Its task is not only to define requirements for the manufacture and assembly of a product, but also to shape production planning, as influenced by quick changes in the field of new materials, technologies, and scientific knowledge, so as to enable the continuous, efficient production of high-quality garments. The planning process should study, in detail, the processing abilities and specific requirements of particular fabrics, and then use that knowledge to define the requirements for the manufacturing and assembling of the products, with a view to developing adequate methods and procedures for performing high-quality, flexible and cost-effective manufacturing processes, as well as determining the time necessary to perform them.

Today, companies are under tremendous pressure to rapidly introduce new products into the marketplace because existing product life cycles are becoming shorter. Therefore, the best way of reducing or minimising risk for an organisation is to carry out better planning than they have ever accomplished in the past. Because of inherent differences in the models and fabrics used, combined with numerous manufacturing processes, increasing requirements for quality, uniqueness, and individuality of garments, as well as the need to shorten manufacturing and delivery-time and reduce costs, manufacturing activities planning plays an important part in achieving a position within market competitiveness, and mass customisation.

Mass customisation is a type of manufacturing system that combines sensitivity to customer preferences with standardisation of processes, and therefore seeks to combine flexibility, low costs and high quality. Mass customisation is a hybrid of mass production and customisation (Lee and Chen, 2000) and in his book, *Mass Customization*, B. J. Pine II defines it as '*the mass production of individually customized goods and services*' (Pine, 1993). He states that a prerequisite of implementing mass customisation is the application of advanced technology, such as the flexible manufacturing system, computer-integrated manufacturing, computer-aided design, and advanced computer technology.

The goals of this strategy of adapting to the user are the development, manufacture, and sales and distribution of products at acceptable prices, and creating the required variety and individualisation of the products, whereby almost every customer can find what he or she wishes to buy. Mass customisation is seldom encountered within the clothing sector, but exists within the wider clothing industry. To utilise mass customisation, manufacturing processes must be flexible, and to be flexible, every step in the manufacturing process must be able to react quickly to changes in product design and to changes in consumer interests and needs. In addition, the clothing industry might need special assembly design rather than work-in-process (Lee and Chen, 2000).

To strengthen competitiveness in the global textiles and clothing industry, companies need to effectively build and sustain strategies for new product development. Generally, consumers want more variety and more direct input into the options that are available, and mass customisation, combined with innovative technologies, has become a key business strategy for new product development (Lim *et al*., 2009). J. P. Gownder and A. Corbett of Forrester Research have, in a paper entitled 'It's Time For Mass-Customized Clothing and Apparel Products', presented three challenges that need to be overcome to succeed (Gownder and Corbett, 2011). Key steps of the mass-customisation success are:

- Step 1: Empower your customers with design assistance.
- Step 2: Focus on fit before style.
- Step 3: Create a concise and simple configurator.

The fact that a variety of major brands, such as Kraft, Hallmark, M&Ms, Wrigley, Nike, Keds, Ford, and many others, have recently introduced important mass customised product offerings (Gownder, 2011) demonstrates that now is the time for product strategists in all industries to consider adding mass customisation – including true build-to-order products – to their product portfolios.

As opposed to mass customisation, requirements for individualisation within the clothing sector have also encouraged experts to develop a new strategy for manufacturing clothing – known as made-to-measure. This is a type of manufacturing system that employs innovative technologies when building an integrated production chain, starting with individual pattern construction and ending with manufacturing clothing made-to-measure, that is, adapting garments to individual preferences and body sizes of customers (Volino and Magnenat-Thalmann, 2000).

The goal of the advancements in made-to-measure manufacturing technology is to develop and integrate several key technologies in a distributed, interactive virtual clothing store, whereby customers can choose and try on 3D clothing which is adjusted to their body measurements, so they are thereby assisted in making appropriate online clothing purchases.

Individualised processes of product manufacture planning, including the manufacturing and assembly processes, and their sequences, are precisely defined, which means specified processing equipment needs to be in place for proper and efficient manufacture. Manufacturing activities planning is supposed, prior to the manufacture of new garments, or prior to performing a specific technological operation, to study in detail:

- manufacturing process possibilities and conditions;
- fabric-specific properties and their impact on the flow of operations, and the quality of manufacture; and
- work methods.

Planning may require new research in methodology and process analysis, and should also predict all the parameters that could impact manufacturing process flow. Key activities of clothing manufacture planning are:

- analysis of clothing manufacture, and the selection of adequate equipment for this purpose;
- planning technological operations;
- planning garment assembly;
- planning a rational process system;
- optimising the arrangement and layout of processing equipment;
- selecting adequate transport systems;
- planning garment manufacturing processes;
- work study; and
- workplace design.

Preparing working sequences is imperative when planning production preparation. The phases of working processes are divided into planning operations, so as to shape a proper sequence of individual operations. The operation is defined as a process of linking individual places of work where work pieces are manufactured using tools or particular machines (Eversheim, 1989).

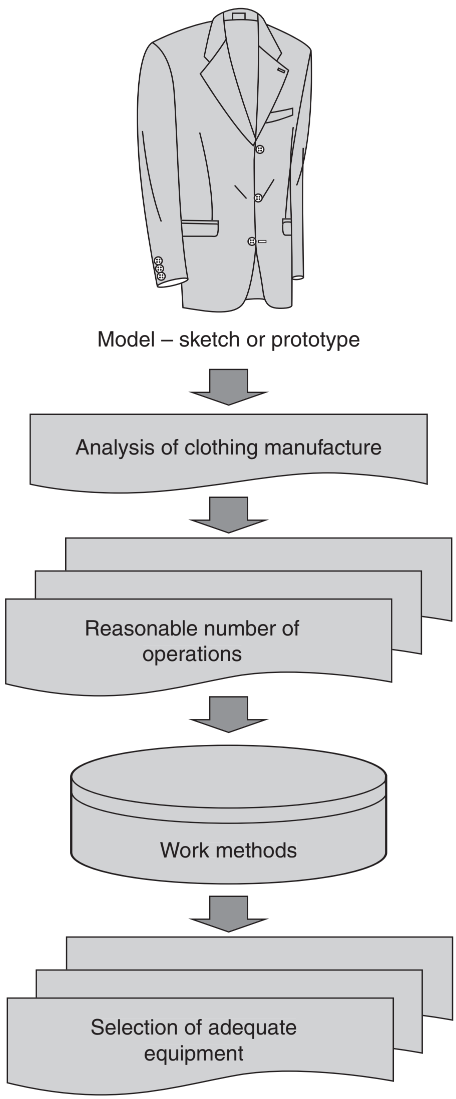
6.2 Analysis of clothing manufacture requirements and selection of appropriate equipment

Clothing manufacture analysis includes dividing the overall manufacturing process, which involves cutting, sewing and finishing, into those numerous operations necessary to make the product. The procedure consists of breaking down the work process into a reasonable number of sub-operations necessary for producing a particular article of clothing, as adapted to industrial clothing manufacture, such that it enables and respects the level of equipment available, offering proper exploitation of this equipment, having in mind the workers' skills and the possible time for performing the operations whilst, at the same time, ensuring high quality and efficiency. A schematic representation of clothing manufacture analysis can be seen in Fig. 6.1.

The analysis performed is used as the basis for selecting the work methods to be used when performing particular operations in the clothing manufacturing process, and to decide which processing equipment will be used. As the selection of suitable equipment depends on the type of operation, dictated by sewing stitch type and/or seam type, it is also necessary to be familiar with sewing stitches and seams, so as to make the selection meaningful.

6.3 Joining technologies

A key aspect of clothing manufacture analysis is the selection of joining technique. Whilst sewing is the traditional method of joining fabrics, newer

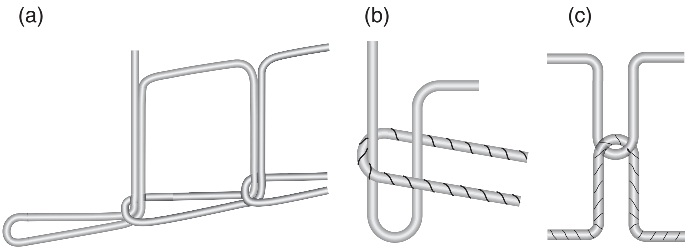


6.1 Analysis of clothing manufacture.

techniques such as welding or adhesive bonding may be more suitable for specific applications

6.3.1 Sewing stitches

A sewing stitch is defined as 'one unit of conformation resulting from one or more strands or loops of thread intralooping, interlooping or passing into



6.2 Stitch formation. (a) Intralooping, (b) interlooping, (c) interlacing.

or through material'. Intralooping is the passing of a loop of thread through another loop formed by the same thread; interlooping is the passing of a loop of thread through another loop formed by a different thread; and interlacing – a term also used in relation to certain stitches – is the passing of a thread over or around another thread or loop of another thread. The types of thread distinction are illustrated in Fig. 6.2.

Various types of sewing stitches have emerged as a result of developments in industrial sewing machines. They are classified according to ISO 4915 into six classes, which variously cover the requirements of joining fabrics together, neatening raw edges, or providing decoration, as follows (ISO 4915, 1981):

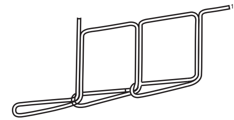
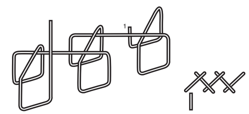
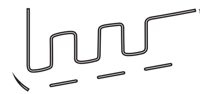
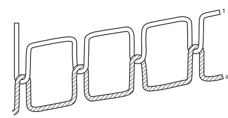
- Class 100 – chain stitches.
- Class 200 – single lockstitches or hand stitches.
- Class 300 – lockstitches.
- Class 400 – multi-thread chain stitches.
- Class 500 – overedge chain stitches.
- Class 600 – covering chain stitches.

Each of these stitches is based on a common kinematic principle of stitch construction, which acts as a common denominator for each major class. Table 6.1 reviews sewing-stitch classifications according to ISO 4915. Individual stitches are designated with three-digits, the first denoting the class, whilst the second and third digits denote the position of each stitch within the particular class. The most common stitch type in use in industry is the lockstitch[1] (type 301), followed by the multi-thread chain stitch[2] (type 401). Lockstitch, as a

[1] **Lockstitch** (type 301) is formed with two groups of threads; a single needle thread and a single bobbin thread. The interlacing of threads lies in the middle of the material. It has the same appearance on both sides. This is important in topstitching as well as in seam joining of facings, collars, pockets and similar garment parts.

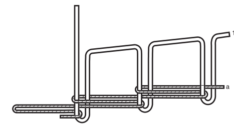
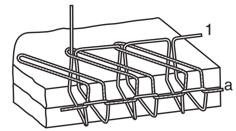
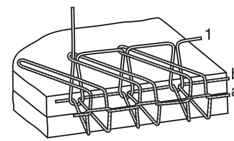
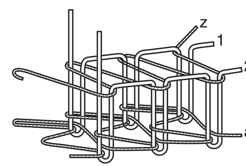
[2] **Chain stitch** (type 401) is formed with two groups of threads; a single needle thread and a single bobbin thread. It has the appearance of a lockstitch on the top but has a double chain effect formed by a looper thread on the underside.

Table 6.1 Sewing-stitch classification according to the ISO 4915

Stitch class: Designation / Name	Stitch type: Designation					Sketch* of stitch	
100 Chainstitches							
Formed from a single thread (needle thread), except for the type 102, which is made from two needle threads.	101	102	103	104	105		101
Used primarily linking and hemming (blind stitch, stitch type 103).		107	108				103
200 Single lockstitches or hand stitches							
Developed from hand stitches, composed of a single system of threads.	201	202		204	205		204
	206			209			
One of the most important is stitch type 209, a machine stitch used for ornamental stitches on jackets, coats and gowns.	211		213	214	215		209
		217		219	220		
300 Lockstitches							
Formed from two thread systems: needle and looper. Stitches are compact and inelastic. Most often used is type 301, that is, basic joining stitch. Stitch types 321–327 produce so-called short seams.	301	302	303	304	305		301
	306	307	308	309	310		
	311	312	313	314	315		
	316	317	318	319	320		
	321	322	323	324	325		
	326	327					

(*Continued*)

Table 6.1 Continued

Stitch class: Designation / Name	Stitch type: Designation					Sketch* of stitch	
400 Multi-thread chain stitches							
Formed from two or more thread systems and characterised by high elasticity. Type 401 is most often used – classified as a joining stitch. Stitch types 411–417 produce so-called short seams.	401 406 411 416	402 407 412 417	403 408 413	404 409 414	405 410 415		401
500 Overedge chain stitches							
Formed from a single or two thread systems, while the loop of at least one thread system goes around the edge of the workpiece. Intended primarily to protect edges, but can also be used to join pieces, for example, stitch type 504.	501 506 511 521	502 507 512	503 508 513	504 509 514	505 510		503
							504
600 Covering chain stitches							
Formed from three thread systems (needle, looper and hidden), only stitch type 601 is formed from two systems. Characterised by excellent elasticity and used primarily in sewing knitted fabrics.	601 606	602 607	603 608	604 609	605		602

*All needle threads are, according to the ISO 4915 nomenclature, designated with numbers 1, 2, 3, …, where, for example, number 3 means triple sewing stitch, while all the looper threads bear the letters a, b, c, …, cover threads are designated Z, Y, X, …(ISO 4915, 1981).

basic joining stitch, also called the 'plain stitch', has enough strength for most purposes, provided that suitable thread is used, and enough stretch, when correctly balanced, for conventional and comfort stretch fabrics stretching to 30% or more. Multi-thread chain stitch, classified also as a joining stitch, is stronger than a similar lockstitch, and possesses a higher degree of elasticity, because of its geometry.

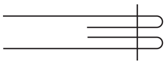
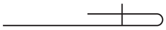
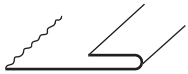
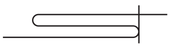
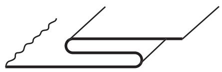
Apart from the above, the standard includes combined stitches, made by combining a multi-thread chain stitch and overedge chain stitch (types 501, 503, 504 or 505), or by combining a multi-thread chain stitch and a covering chain stitch (type 602). The designation for a combined stitch includes the designations for both stitch types; for example, 401.503. If the combined stitch is done within a single operation (i.e. simultaneously), the designation is in brackets: (401.503).

6.3.2 Sewing seams

According to ISO 4916, a sewing seam is defined as 'the application of a series of stitches or stitch types to one or several thicknesses of material' (ISO 4916, 1982). In common parlance, a stitched seam is defined as a linearly formed joint of two or more fabric layers (sewing work piece components), made by a series of sewing stitches or stitch types, or made on a single sewing component in various configurations.

Sewing seams are divided into eight classes according to the type and minimum number of work piece components within the seam. Individual sewing work piece components can be unlimited, limited from the left or right sides, or limited on both sides. Each sewing seam is identified by a numerical designation composed of five digits, where the first digit denotes the seam class (from one to eight), the second and third the arrangement of the work piece layers or the configuration of work piece components within the seam, and fourth and fifth the position of the stitch or sewing needle penetration, that is, differences in location of needle penetrations or passages and/or mirror images of the material configuration (as indicated by the second and third digits); see Fig. 6.3. The sewing seam classes are presented in Table 6.2. The choice of seam type is determined by its required performance and appearance, and is directly dependent on aesthetics, the functional requirement of the individual garment, and comfort.

Seam performance refers to strength, elasticity, durability, security and comfort, and maintenance of any specialised fabric properties such as flameproofing or waterproofing. Seams must be as strong as the fabric, in directions both parallel and at right angles to the seam. They must also stretch and recover with the fabric. Good appearance in a seam normally means smooth fabric joins with no missed or uneven stitches and no damage to the fabric being sewn.

Location of needle penetration or passage		Material configuration	Penetration or passage of the sewing needle
Sketch	Designation		
	1.06.01/301		Sewing needle penetrates the workpiece.
	6.02.02/103		Sewing needle penetrates the workpiece tangentially and does not pass through, e.g. sewn by blind* stitch: used to work the length of outer garments, etc.
	6.06.01/503 6.06.01/505		Sewing needle only touches the fabric and does not penetrate it, e.g. sewn by stitch type 503 or 505.

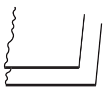
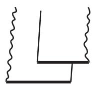
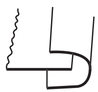
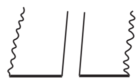
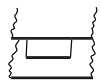
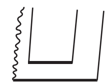
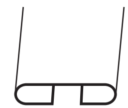
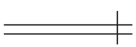
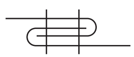
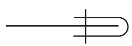
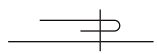
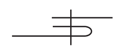
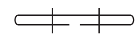
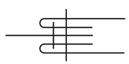
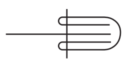
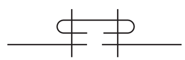
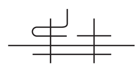
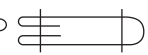
6.3 The location of sewing needle penetration or passage throughout the area of the seam. (*Blind stitch is a stitch which is not visible on one side of the fabric or fabrics being sewed. The blind stitching version, type 103, utilises a curved needle in order successively, to penetrate partially into the fabric, and then into the hem edge, while showing minimally or not at all on the right side of the garment.)

6.3.3 Welding and adhesive bonding techniques

A welding technique, or threadless joining technique, is used to join 100% synthetic[3] (e.g. polyamide (PA), polyester (PES), polypropylene (PP) or polyethylene (PE) fabrics, etc.) or fabric blends with up to 40% natural fibres, which are compatible when melted together. As a general rule, the fabrics to be welded must be of the same thermoplastic. From a constructional point of view, the material to be melted may be the thermoplastic fibres of the fabric, a thermoplastic coated textile (such as polyvinylchloride (PVC) or polyurethane (PU) coated textiles, etc.), membrane, and laminate with membrane (e.g. polyamide laminated with polytetrafluoroethylene (PTFE) membrane, polyester laminated with bi-component polyurethane/

[3] Sometimes the synthetic group is erroneously called the 'thermoplastic group'. Although many synthetic fibres are thermoplastic (they repeatedly soften when heated and harden when cooled), others do not melt when heated (Hatch, 1993).

Table 6.2 Stitched seam classification according to the ISO 4916

Workpiece components	Workpiece components 1	2	3	4	5	6	7	8
	2 or more	1 or more	1 or more	1 + 1 or more in the same horizontal plane	0 or more	1	1	–
	–	1 or more	–					–
	–	–	–	–	1 or more	–	–	–
	0 or more	0 or more	1 or more	0 or more	0 or more	–	1 or more	1 or more
Minimum total number of components	2 or more	2 or more	2 or more	2 or more	1 or more	1	2 or more	1 or more
Basic configuration of workpiece layers								
Important seam types	 1.01.01	 2.04.04	 3.01.01	 4.03.03	 5.05.01	 6.03.03	 7.12.01	 8.02.01
	 1.06.02	 2.42.04	 3.05.03	 4.06.01	 5.26.01	 6.08.01	 7.14.01	 8.06.02

PTFE membrane, etc.) or an adhesive film added at the joint in combination with the fabric fibres.

A welding technique is generally defined as the joining of two or more fabric layers, made of the same material, by applying heat and pressure (Albrecht *et al*., 2003; Jones, 2005; Kehry, 2007). The term 'welding' refers to all types of bonding and sealing, as in point bonding or the continuous sealing of material. The welding process consists of three individual processes that are carried out almost simultaneously at the point of welding:

1. Heating until melting is initiated.
2. Compression.
3. Cooling down until the connection is solid.

There are several types of welding, of which five are mostly used during the clothing manufacturing process and other textile products for technical applications. They are:

1. hot air welding;
2. hot wedge welding;
3. high-frequency welding;
4. ultrasonic[4] welding; and
5. laser[5] welding.

Hot air, hot wedge, ultrasonic and laser welding are generally categorised as so-called 'rotary welding'. Rotary welding is a continuous process whereby the fabric layers move continuously through the machine – the welding area, usually pulled along by a pair of drive wheels.

The welding technique allows sealed seams to be used in applications such as outdoor clothing, workwear, leisurewear and protective clothing, as well as hems in medical disposable products, and products of technical textiles. The most important fields of application are:

- production of weatherproof clothing, workwear, sportswear and leisurewear, often with integrated membranes;

[4] **Ultrasonic** – the term refers to acoustic frequencies above the range audible to the human ear, or above approximately 20 000 Hz. Ultrasonic energy is mechanical vibratory energy, which operates at frequencies beyond audible sound (Flood, 1989).

[5] **Laser welding** technique uses transmission of energy to weld without melting the outer surface. The process melts a thin layer of the fabrics without affecting the outer surfaces by transmitting the laser energy through the outer fibres (Hänsch, 2007).

- production of healthcare clothing and similar products, such as one-way clothing, hospital linen, etc., made especially of non-wovens;
- joining seams on water-repellent and breathable membrane sheeting such as Gore-Tex and Sympatex for sports, and trekking shoes, as well as all kinds of weatherproof clothing and sportswear;
- welding process for applications such as airbag construction, bed assembly, medical furniture, and protective clothing;
- production of tents, awnings, light tarpaulins, protective covers, car covers; and
- joining seams on insulating and filter tubes, etc.

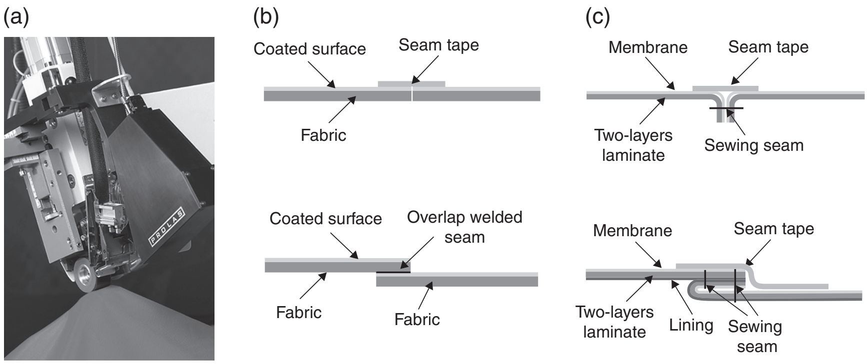
Various types of welded seam have been developed according to different fields of application. In general, a welded seam can be classified as a joint seam, which is produced directly by welding, whereby the two fabric parts are transformed into one material structure by binding at a molecular level, and a welded seam using adhesive film[6] sealing, which are then used with previously sewn seams to prevent water and air through the stitch holes.

For highly engineered fabrics that provide a barrier to particles, liquids or gases, the main limitation is the joining of these fabrics, because sewing penetrates the material and resealing is required during a second taping process. Typical applications of welded seams are illustrated in Fig. 6.4. Figure 6.4a presents an example of a single-layer flat-welded seam using hot-melt adhesive tape and an overlap seam without adhesive tape, whilst Fig. 6.4b illustrates a welded seam with an adhesive film on top of previously sewn seams.

6.4 Work analysis

The starting point of work analysis (technological analysis) is a prepared clothing prototype or model technical sketch with a brief description, and specific manufacturing instructions, and should be accompanied by all the data necessary to present the final product properly and to analyse the work. See Fig. 6.5. The analysis of work or work processes presumes a detailed study of individual phases or steps in the process, and breaking down the process into a rational and logical number of sub-units, that is, operations, adequate for clothing manufacture under the conditions of an industrial organisation.

[6] **Adhesive film,** or the so-called seam tape, is a thermoplastic film for bonding two fabrics together or is the sealing tape, which has a thermoplastic adhesive coating on one side.



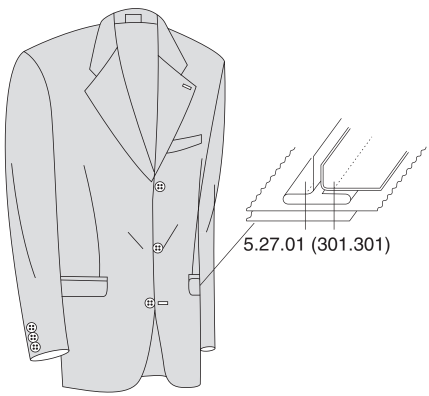
6.4 Seam welding machine and typical welded seam types. (a) Seam welding machine. (b) Flat-welded seam with adhesive tape and overlap welded seam with adhesive tape. (c) Welded seam with adhesive film on top of previously sewn seams.

From a technological point of view, the work is shaped by the so-called man-machine system, that is, a system in which a human operator and a machine are integrated, for example, a closed-loop control system where a machine identifies a variance which is then corrected by a human operator who uses the machine to verify the variance has been corrected. The work necessary to produce or process a particular article consists of individual phases or steps. These phases are concerned with various types of work as performed at various workplaces, and can be interconnected by space or technology. Contrary to the work phase, an operation is a particular part of article processing, performed at a particular workplace. As an operation concerns a particular part of processing, from picking-up to laying-off the object, it can be subdivided into sub-operations in advance which are, in turn, composed of individual movements or activities (Žunič Lojen and Geršak, 1994).

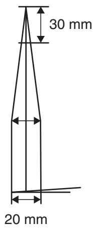
Work analysis is particularly important for processes such, as sewing, which are composed of diverse operations that differ by type, number, and duration of sub-operations. Numerous factors impact on the structure of operation, such as operation type and degree of complexity, workability, that is, fabric behaviour during the sewing process, workplace design, and work methods. This is why it is essential to be familiar with the operation structure, in order to break down individual phases of the work process in a rational manner. The analysis of operation structure is used to subdivide the operations into logical sub-operations which are, in turn, a basis for determining the necessary times and the amount of particular sub-operations, and as a basis for the parameters of workplace design.

Sewing operations are generally composed of the following technological sub-operations:

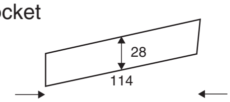
Product type: men's suit jacket	Model name: Artemis
Model drawing (sketch)	Peculiarities



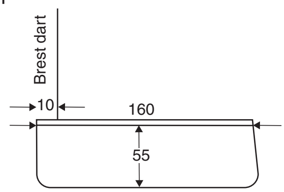
Breast dart



Breast pocket



Side pocket



Information on the model

Conventional suit jacket with chequered lapel, single-breasted, with three buttons. The front part has interlining built-in. Chest pocket is piped with a bar, whilst side pockets are piped and flapped.
The jacket has vents at the centre back and on the sleeves. Sleeve vents have three buttonholes and buttons.

Lapel width	92 mm
Collar width	40 mm
Seam width	
Edge seams	7 mm
Side seams	15 mm
Other seams	10 mm

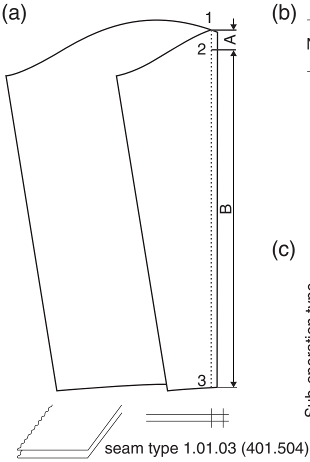
Notes	Prepared by Date: 3.3.2012

6.5 Model technical sketch with description.

- Preparation for sewing.
- Sewing with work piece guidance.
- Manipulating and handling the work piece when sewing.
- Laying-off the work piece at the end of sewing.

It is necessary to be familiar with technological sub-operations in order to subdivide the work into operations, as well as to determine the number of

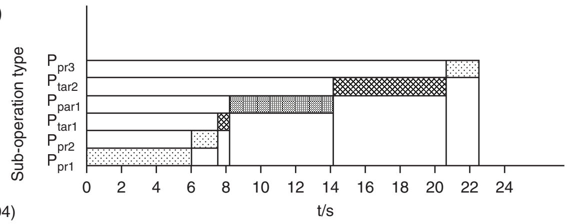
(a)



(b)

Number	Sub-operation type	
	Name	Designation
1.	Manually picking up both work piece layers	P_{pr1}
2.	Position the work piece under the point of sewing	P_{pr2}
3.	Machine-manual sewing of the segment A	P_{tar1}
4.	Stopping the sewing and aligning work piece layers	P_{par1}
5.	Machine-manual sewing of the segment B	P_{tar2}
6.	Stopping the sewing and manually the work piece off	P_{pr3}

(c)



6.6 Technological operation of sewing a two-piece sleeve. (a) Sewing operation with two segments. (b) Structure of sewing operation: sub-operations. (c) Structure of sewing operation: timings.

operations necessary, so as to ensure an optimal relationship among particular sub-operations, which are all of the utmost importance in achieving an efficient, high-quality and continuous technological process flow. Figure 6.6a offers an example of the operation when sewing a two-piece sleeve, using a special sewing machine, employing seam type 1.01.03(401.504). A graphic representation of the associated operation structure can be seen in Fig. 6.6b (Žunič Lojen and Geršak, 1994).

6.5 Identifying work methods

It is necessary to define the work methods to be used to ensure an efficient, high-quality and uninterrupted working-process flow, that is, the predetermined manner of performing the work-flow, including all the activities of the operator, from the way the work object is picked-up, to preparation and handling during the course of performing operations, until the moment of laying-off the work piece. The function of this study is to determine the equipment, tools, working conditions and work method that will enable the operator to produce the maximum number of work units in a given time with minimal expenditure of human energy.

The type of operation should be respected, as well as the quality requirements associated with it, and the accepted rules for the economic performance of individual movements. The work method, which is one of the technological factors in workplace design, should always be designed in relation to the system, which includes numerous interlinked elements affecting each other.

Knowledge of adequate work methods is of extreme importance when planning and optimising sewing, primarily due to the high level of complexity regarding the process and also because of the general requirements when performing sewing operations. In order to perform the operation, the operator goes through the following work cycle phases:

- picking-up[7] the work piece layer(s);
- positioning[8] the work piece layer(s) on the machine bed before the sewing begins;
- sewing after the work piece layer(s) contacts the sewing machine bed; this phase may be divided into two or more parts, because the operator stops during the sewing operation in order to reposition the work piece layer(s); and
- discarding[9] the work piece or sewed garment part.

The work methods selected should involve all the activities performed by the operator, from the process of picking-up previously cut garment parts, to their preparation and guidance when sewing, and finally to the process of discarding the sewed garment part, or 'laying-off' the work piece. A properly selected method of work offers the possibility of sewing longer segments of seam contours without the need for stopping the machine, which results in higher seam quality as a more uniform sewing process flow ensures lower oscillations in the stitching speed.

As the type of sewing operation selected depends upon the model type and shape, or the garment part's type and shape, which offers information on the seam contours' shape[10] and length, the work method selected for a particular sewing operation can include a single or different ways of guiding the work piece. In relation to the forms of particular sewing operations and seam contour shapes and lengths, there are four methods for guiding[11] the work piece (Liekweg *et al*., 1983):

[7] **Pick-up** – phase that starts when the operator's hand(s) begin to travel toward the work piece layer(s). This phase ends when the work piece layer(s) is (are) grasped by the hand(s).

[8] **Initial position** – phase that starts when the hand(s) begin(s) transporting the work piece layer(s) to its initial sewing position on the sewing machine bed before the sewing begins, and ends when the work piece layer(s) is (are) in the proper place on the sewing machine bed for the machine to begin sewing.

[9] **Discard** – phase that starts when the hand(s) begin(s) to travel toward the work piece or sewed garment in order to discard the sewed part. This phase ends when the hand(s) release(s) contact with the work piece.

[10] **Seam contour shape** – means the form of sewed contour; for example, the operator sews one of three basic geometric patterns: straight lines, angles, or curves.

[11] **Work piece guidance** as a prescribed method of guiding work piece components in sewing was developed at the Fachochschule in Sigmaringenu, and is known as optimal sewing methods (Liekweg *et al*., 1983).

1. Basic method of guiding a work piece.
2. Work piece guiding with puckering.
3. Flowing method of guiding a work piece.
4. Combined method when guiding a work piece.

The requirements relating to the economy of movement and work piece layer positions should also be respected when planning the methods for guiding work pieces. This means that:

- the positioning of work piece layers on the surface should enable repeated picking-up using both hands;
- the work piece should be picked-up within the normal work-reach (i.e. with minimal lower arm movements);
- the operator picks-up individual work piece layers, employing the arm that guides them in the process of sewing; and
- work piece layers should be picked-up so as to position them at the point of sewing, without additional movements and shifts, or with minimal additional shifts.

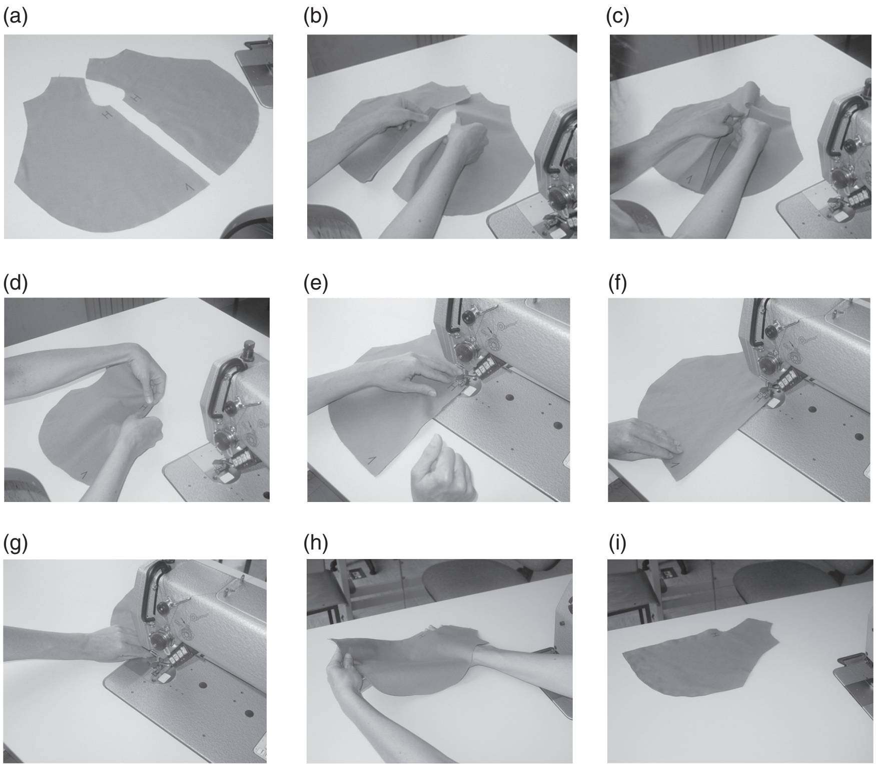
6.5.1 Basic method of guiding a work piece

The work piece is guided, in principle, by the left hand in such a way as to enable uninterrupted sewing, in a transverse direction, and in the direction of sewing. When two or more layers are sewn they are guided together. Depending on the seam's length, sewing is done with one, two or three control-points. Figure 6.7 shows the typical technological sub-operations (such as work piece layer preparation, picking-up layers with both hands, putting layers together, transferring joined layers, positioning and tacking,[12] sewing, seam tacking, laying-off the work piece and the work piece laid-off after sewing) by the basic method of guiding a work piece, with one control-point, whilst the typical technological sub-operations by the same method of guiding a work piece, although note with two control-points, can be seen in Fig. 6.8.

6.5.2 Work piece guidance with puckering

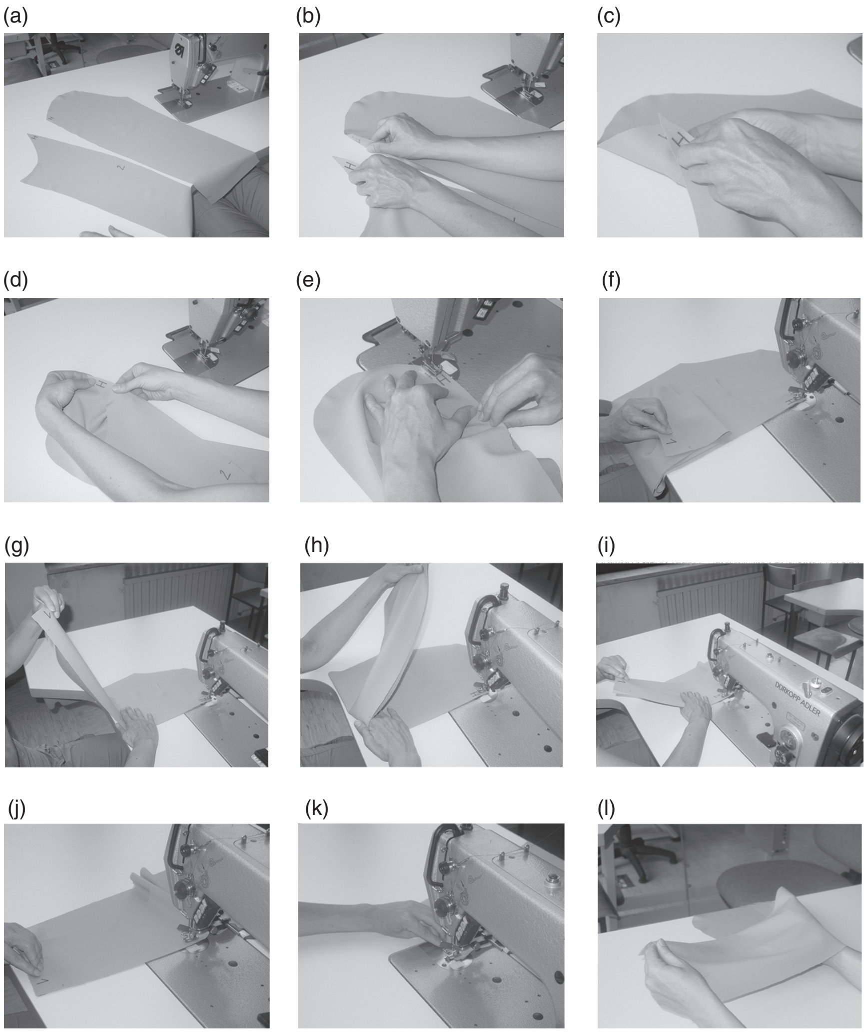
When this method is employed, the work piece layers are guided separately. The upper layer is, in principle, puckered using the left hand, whilst

[12] **Tacking** is a stitching sequence that (a) prevents a stitch chain (in a seam or otherwise) from opening; and (b) hold two pices of material (cloth, braid, tape, elastic braid, buttons, etc.) intact at one point or small area.



6.7 Basic method of guiding a work piece with one control-point – O2E023. (a) Work piece layer preparation; (b) picking-up layers with both hands; (c) putting layers together; (d) transferring joined layers; (e) positioning and tacking; (f) sewing; (g) seam tacking; (h) laying-off the work piece; (i) work piece laid-off after sewing.

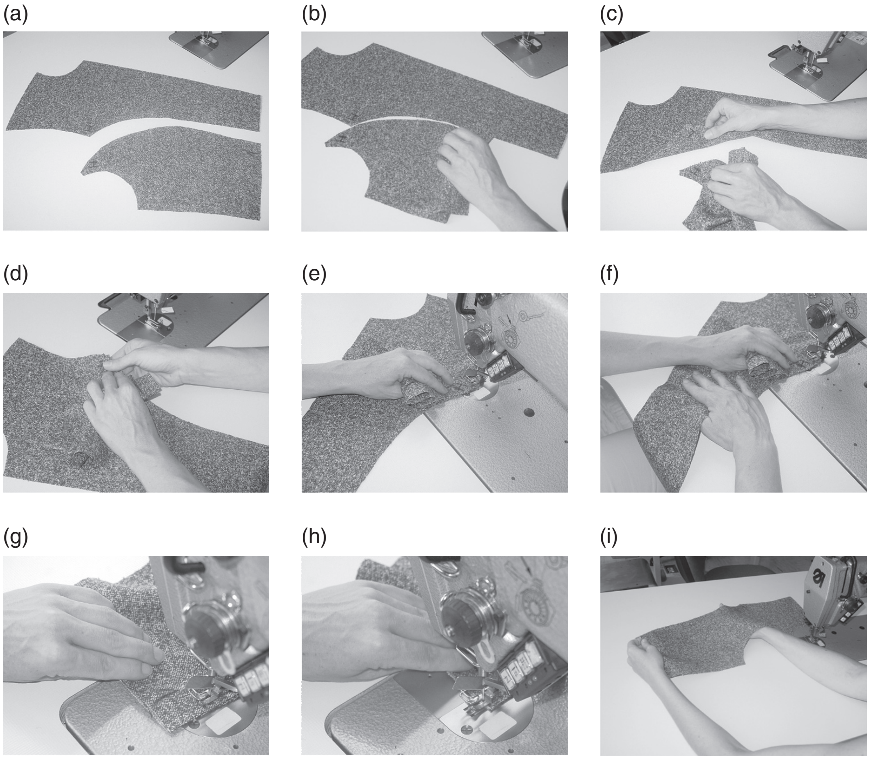
the lower layer slides between the thumb of the right hand and the palm, or is folded, as shown in Fig. 6.9. The work piece is generally guided transversally, with the distance between hands and sewing needle as great as possible, and at least 15 cm apart, so that the operator can react in time and correct any deviations from the planned sewing direction. This method of guiding a work piece is used in sewing work piece layers of different contour shapes, especially in sewing together work piece layers with curved contours and those with straight ones, as well as in sewing work piece layers with various radii of contour curvature. Control-points are defined in relation to the number of work piece layers. If a single layer is sewn, the method employs one control-point; with two layers the method needs two control-points.



6.8 Basic method of guiding a work piece with two control-points – O2D064. (a) Work piece layer preparation; (b) picking-up layers with both hands; (c) putting layers together; (d) transferring joined layers; (e) positioning and tacking; (f) holding – control-point 1; (g) holding – control-point 2; (h) sewing; (i) sewing with work piece opening; j) Sewing – work piece guiding; (k) seam tacking; (l)laying-off the work piece.

6.5.3 Flowing method of guiding a work piece

Here the layers are guided separately. The upper layer is guided with the left hand, the lower with the right, whilst layers are mostly guided transversally. The work piece layers come into contact in the vicinity of the

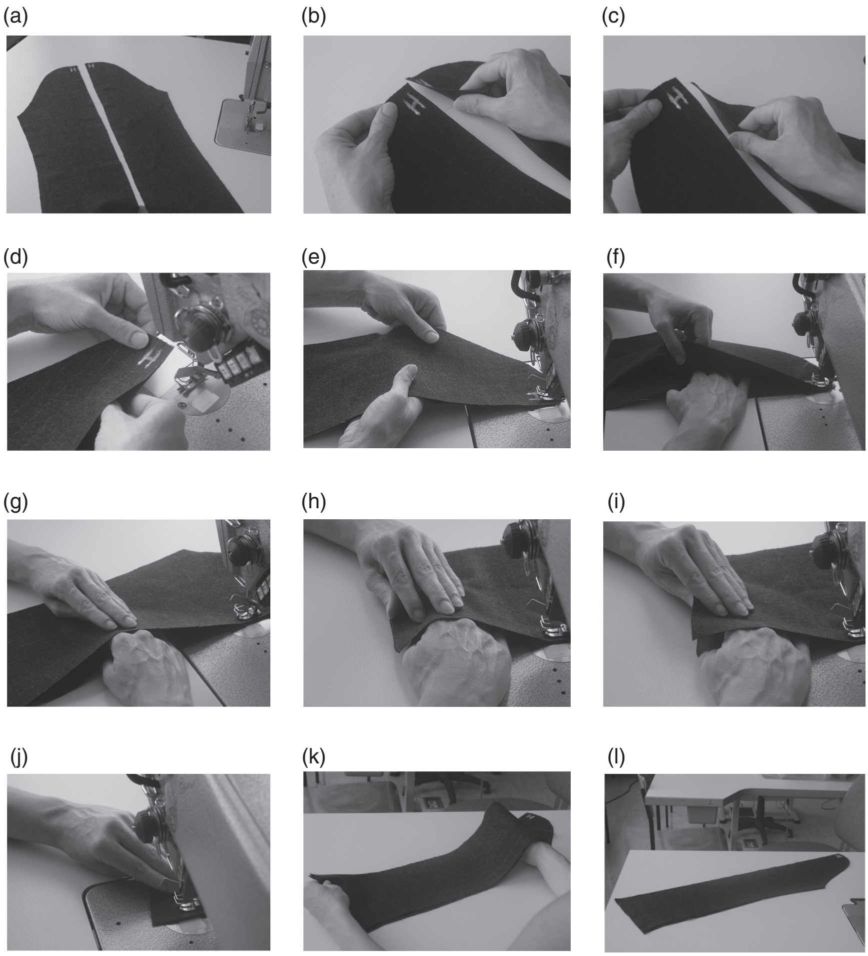


6.9 Work piece guiding with puckering – G2E037. (a) Work piece layers preparation; (b) puckering the upper layer; (c) picking-up the lower layer; (d) joining work piece layers; (e) positioning and seam tacking; (f) work piece guiding in sewing; (g) holding – control-point; (h) seam tacking; (i) laying-off the work piece.

point of sewing. This method of work piece guidance is used when sewing a single-layer or two-layer work piece with straight or gently curved contours, or with different contour radii that do not differ too much, as seen in Fig. 6.10.

6.5.4 Combined method of guiding a work piece

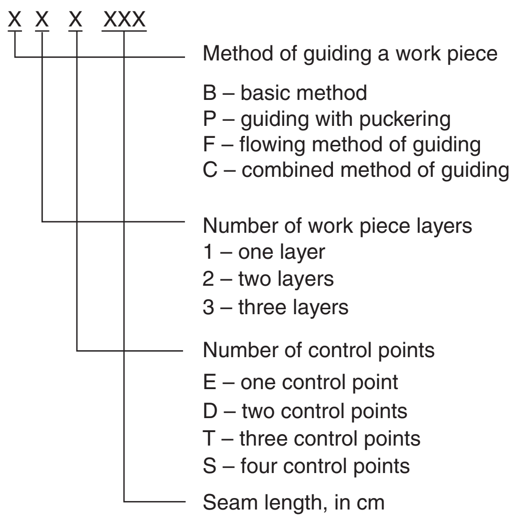
The combined method of guiding a work piece is, in principle, a combination of the above-mentioned methods, that is, of the basic and flowing method, of the basic method and guiding with puckering, or flowing method and guiding with puckering. Both methods are used at the same time, or consecutively, the point being to disallow sewing from being stopped. Proper



6.10 Flowing method of guiding a work piece – P2D073. (a) work piece layers preparation; (b) picking-up with both hands; (c) joining work piece layers; (d) transfer of joined layers; (e) positioning and seam tacking; (f) preparation for sewing; (g) sewing – work piece guiding; (h) sewing – work piece guiding; (i) sewing – work piece guiding; (j) sewing – guiding – seam tacking; (k) laying-off the work piece; (l) work piece laid-off after sewing.

selection of the work method definitely impacts on the quality of the created seam, as well as on the average seam length made in one sub-operation, that is, without stopping or decelerating the sewing machine, which lowers the time necessary to perform the operation in question (Liekweg *et al.*, 1983; Geršak, 1987, 1989).

The methods of work piece guiding can be represented by a six-digit designation, where the first digit denotes the method of guiding the work piece, the second the number of work piece layers, the third the number of the control-point, whilst the rest express the length of the seam contour in centimetres. The designation of work piece guidance thus assumes the following form (Liekweg *et al.*, 1983):



To ensure optimal sewing it is necessary, in addition to the above, to obey the rules of direct work piece manipulating, handling and guidance (Liekweg *et al.*, 1983):

(a) The work piece should be guided as far from the sewing point as possible, thus enabling the operator to control sewing at a predetermined distance from the sewing needle. This enables the operator to make timely corrections if deviations occur from the required sewing direction.
(b) The work piece should be held with the left hand at a proper distance from the edge, so it is not necessary to adjust the hold while the hand slides beside the sewing needle.
(c) In the case of seam tacking at the beginning of the seam, the work piece may be positioned at the initial sewing position, that is, under the sewing point (sewing needle) so that it lies between 5 and 10 mm from the beginning of the seam. Backwards sewing follows, that is, seam tacking, and the sewing continues forwards, with no interruption.

(d) When the seam is tacked at the end, it follows the tacking only by sewing backward, approximately 5–10 mm.
(e) Workpiece laying-off should occur within regular working reach, employing as simple a movement as possible.

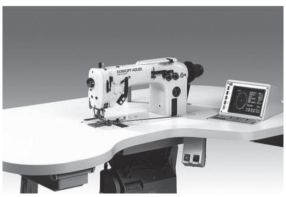
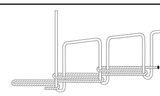
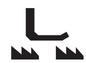
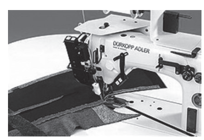
All the methods for guiding a work piece, as described above, generally require a longer time for work piece layer preparation before sewing. Sewing is usually performed without control-points, or just a few, which ensures an undisturbed work process. Efficient work piece guidance employing the above methods presumes the adequate selection of a proper sewing machine and work aids.

6.6 Selecting processing equipment

The correct processing equipment is required in order to perform operations following a work plan. Processing equipment includes, simply speaking, machines, tools and devices (Eversheim, 1996). Analysis should involve selecting the processing equipment, but also a necessary auxiliary device that ensures the high-quality execution of the different technological operations. A database for processing equipment should be created for the purpose of meaningful selection and exploitation of the equipment. It should include key information on the purpose, function, and possibilities of work aids and auxiliary devices as well. The most important information on the equipment is collected in a so-called processing equipment list – see Fig. 6.11 – which is a document that includes all the technical characteristics of the equipment, its area of use, work aids, capacity and price.

The processing equipment list, known also as the processing equipment specification, is a document that refers to the operating details and processing links of any machine used by the operator. Processing equipment for a particular operation in clothing manufacture is selected in a rational manner on the basis of technological measurements and economic feasibility; see Fig. 6.12. Figure 6.13 shows a part of the technological analysis when manufacturing a man's jacket, with the equipment to be used in the operation of pocket piping.[13] As high-quality sewing operations require a wide range of processing equipment (sewing machines that differ by stitch class, and type, purpose, function, and technical characteristics), further chapters will include descriptions of the most important sewing machine properties.

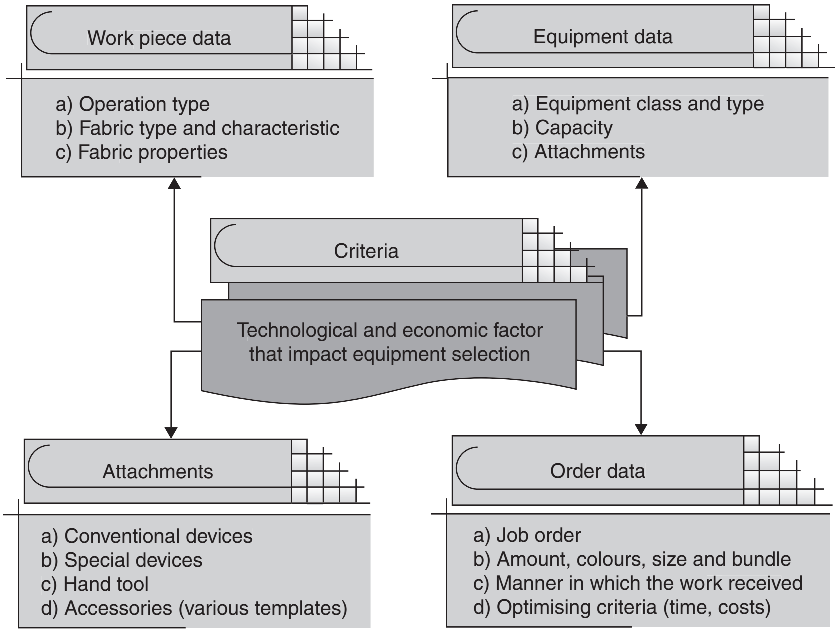
[13] **Piping** – decorative hem with a piping tape, that is, inserting maximally 5 cm wide decorative tape between two layers, which can be folded lengthwise, bias cut or specially woven coloured tape with a thickened edge (Schierbaum, 1982).

<table>
<tr><td colspan="3">Description of
processing equipment</td></tr>
<tr><td>Equipment type</td><td colspan="2">Sewing machine</td></tr>
<tr><td>Equipment name</td><td colspan="2">Special sewing machine for screen-assisted bridle-taping</td></tr>
<tr><td>Designation: TO-SS03</td><td colspan="2">Class and type: Dürkopp 550-12-12</td></tr>
<tr><td>Manufacturer: Dürkopp Adler</td><td>Year of manufacture: 2010</td><td>Purchase price</td></tr>
<tr><td>Supplier: Slomatex</td><td>Year of purchase: 2011</td><td></td></tr>
<tr><td>Area of use</td><td colspan="2">Screen-assisted taping of the armhole and
pre-ruffing of the cuff ball – sleeve head</td></tr>
<tr><td colspan="3">Technical characteristics</td></tr>
<tr><td rowspan="2"></td><td colspan="2">Stitch class: multi-thread chainstitch
Stitch type: 401 
Feed system type:
variable foot top feed combined with
the differential bottom feed </td></tr>
<tr><td colspan="2">Function: pre-gathering and bridle-taping workpiece layers
Control : numeric control</td></tr>
<tr><td>Stitch length:
minimal 2,5 mm
maximal 6,0 mm
Needle gauge Nm 80–100
Stitching speed 3200 stitch min^{-1}</td><td colspan="2">Numerically-controlled pre-gathering
of the sleeve in the armhole area
Possibility:
29 different ruffing values available
for 13 sections per seam. </td></tr>
<tr><td>Designed workplace
Dimensions:
length 1600 mm
width 1530 mm
height 951 mm</td><td colspan="2">Screen-assistend, dialogue-oriented
programming (Tech-in procedure).
Individually programmable control.
Appliance for the automatic feeding
and cutting of the bridle-tape. </td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>Notes</td><td>Capacity:</td><td>Originator:
Date:</td></tr>
</table>

6.11 An example of a processing equipment list.

6.7 Types of sewing machine

The efficiency and quality of a particular sewing operation depends directly on selecting the proper sewing machine and accessories. It is important to be familiar with the technical characteristics of various sewing machines, in order to decide what kind of machine is adequate for a particular operation, or which operation will be performed in the best manner on a particular sewing machine.



6.12 Criteria for the selection of processing equipment.

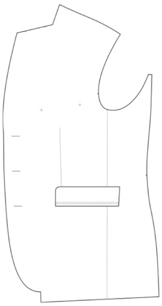
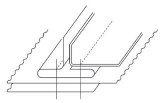
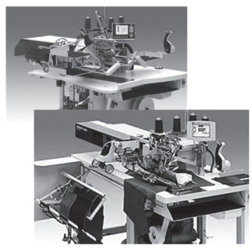
Sewing machines can be considered in terms of general working and from the viewpoint of their technical characteristics, as shown in Fig. 6.14. Sewing machines can be classified into the following groups:

(a) Basic sewing machines, which include:
- sewing machines that sew with a lockstitch (stitch type 301); and
- sewing machines that sew with a multi-thread chain stitch (stitch type 401).

Basic sewing machines using a lockstitch are primarily intended for joining garment parts that are not exposed to higher loads in wear. The seam is compact and inelastic. When garment parts are exposed to higher loads it is necessary to use basic sewing machines that employ a multi-thread chain stitch, as such a seam is elastic and allows for higher loads.

A large number of work aids are available for basic sewing machines, and attachments that can relieve the operator of some of the handling associated with sewing operations.

(b) Special sewing machines are intended for particular technological operations. Apart from basic general-purpose sewing machines, there is also a huge range of high-performance machines that are built to undertake one operation only at a consistently high level of quality. Generally speaking, they can be divided as follows:

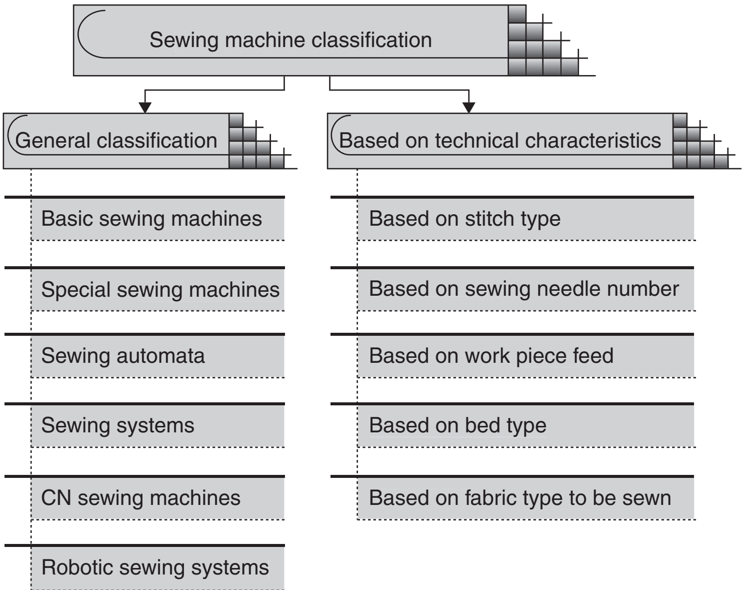
Operation	Pocket piping	
Specification		
Operation sketch	Seam class and type	Equipment class and type
	 5.27.01 (301.301) 	a) Basic sewing machine that sews with a lockstitch, stitch type 301 b) Double-needle special sewing machine for pocket piping c) Double-needle sewing automaton for pocket piping, equipped with photocells d) Computer-aided sewing system for pocket piping, equipped with a direct drive and a device for automatic work piece laying-off
Notes	Capacity:	Originator: Date:

6.13 A detail of the analysis with equipment selection.

- By function, with machines for sewing zips, for pocket piping, for sewing knitted articles, corsets, etc.;
- By sewing-stitch class and type, including sewing machines that use all stitch types, except stitch types 301 and 401 (e.g., special sewing machines with blindstitch (stitch type 103), with a zigzag stitch (stitch types 304 or 404), special sewing machines that attach pocket bags (stitch type 408), those that employ overedge chain stitches (stitch class 500), as well as the one employing covering chain stitches (stitch class 600), and so on).

(c) Sewing automata are advanced special sewing machines. They are characterised by the ability to perform, when the work piece is positioned and the machine is actuated, automatic sewing, to stop with the sewing needle in the upper position, cut the thread, release the work piece and sometimes lay it off. By their function, they can be:

- sewing automata for short seams (for making buttonholes, for attaching buttons, strengthening, etc.);



6.14 Sewing machine classification.

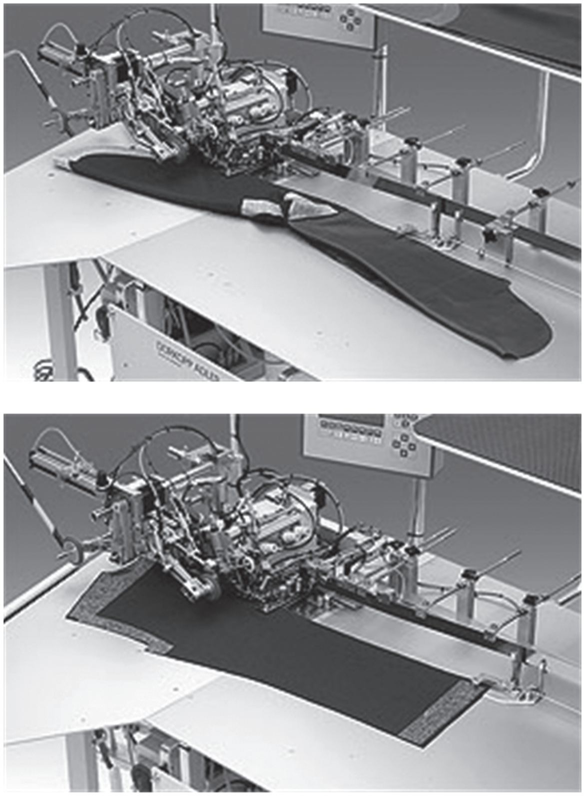
- sewing automata for long seams (for making darts, sewing side seams on suit jackets, jackets, trousers, etc.). An example of a sewing automaton for long seams and a device for automatic work piece laying-off can be seen in Fig. 6.15.

(d) Sewing systems belong to the group of advanced sewing machines. They possess all the characteristics of sewing automata and enable, when the work piece is positioned and the machine actuated, the automatic performances of two or more sub-operations. When sewing is completed, they release the work piece and lay it off automatically. They include sewing systems for making buttonholes, for button sewing, for pocket fastening, and so on. An example of a sewing system for attaching pockets can be seen in Fig. 6.16.

(e) Numerical-controlled sewing machines are those machines through which the work piece is automatically guided, similarly to sewing automata and sewing systems, following a predetermined seam contour line, based on numerical data on a seam contour. The numerical data are stored in the processing computer memory and are associated with work piece movements when sewing. Computer Numerical Control (CNC-controlled) sewing machines, have been introduced recently. An example of a CNC-controlled sewing machine is the CNC sewing

(a)

(b)



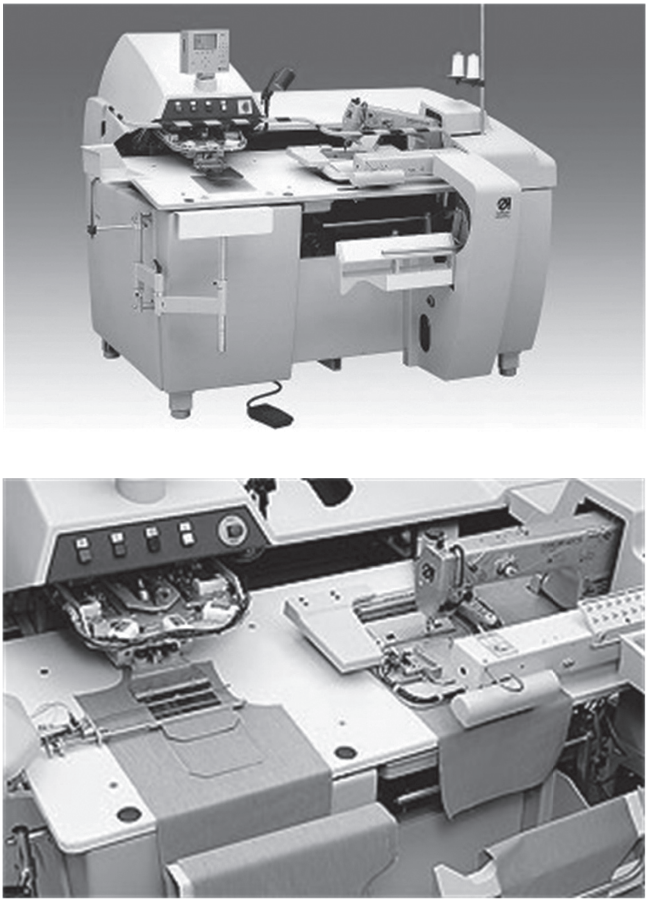
6.15 Sewing automaton for long seams with automatic photocell thread detection in a seam contour: (a) sleeve seam; (b) center back seam.

automaton for bartacking[14] buttonholes (see Fig. 6.17a), and for making lockstitch buttonholes (Fig. 6.17b). (f) Robotic sewing systems are sewing systems equipped with a multifunctional manipulator,[15] which can be re-programmed and designed so as to enable easy work piece layer manipulations. Figure 6.18 shows a robotic sewing system used for sewing the pockets of a man's jacket.

[14] **Bartacking** – is the sewing of a dense tack across the open end of a buttonhole. The machine sews a fixed number of stitches across the end of the buttonhole, then oversews them at right angles with a series of covering stitches.

[15] **Manipulator** [Gem. *Manipulator* from Fr. *manipulateur*] – is a device used to manipulate materials without direct contact.

(a)
(b)



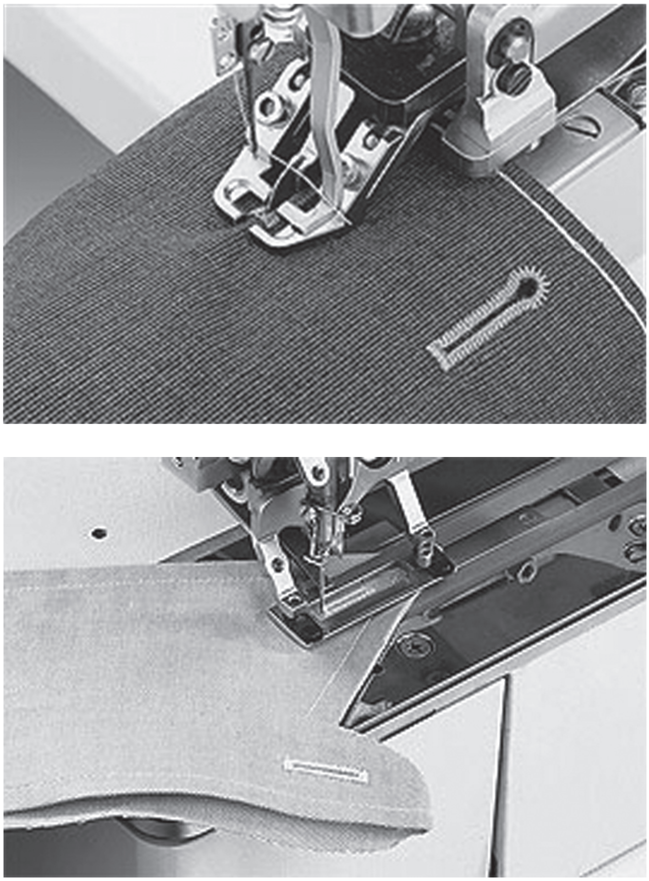
6.16 An automated sewing system for attaching shirt pockets (a and b).

6.7.1 Types of sewing machines based on technical characteristics

The technical characteristics of sewing machines are extremely important from the point of view of machine utilisation. Based on these characteristics, sewing machines can be divided by sewing-stitch class and type, the number of sewing needles used, the type of feed mechanism, bed type, and type of fabric sewn. Sewing machines are grouped as shown in Fig. 6.14. Machines classified by the number of sewing needles and the type of stitch used can be seen in Fig. 6.19.

The work piece feed mechanism is one of the most important technical characteristics of a sewing machine, since the movement of the work piece

(a)
(b)

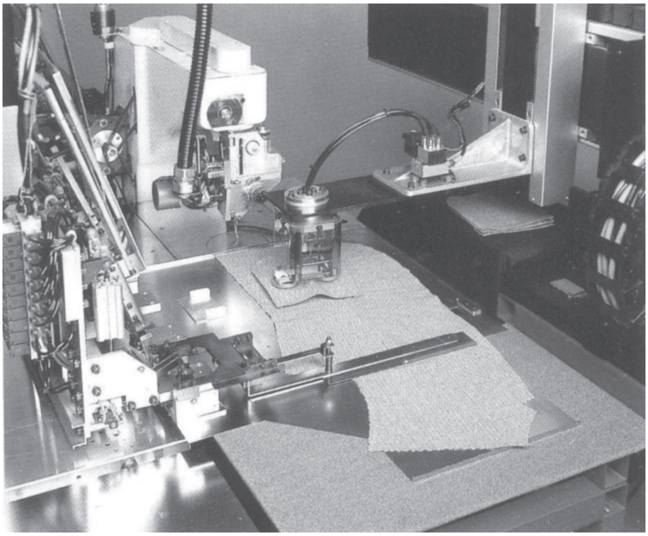


6.17 CNC computer-aided numerically-controlled sewing automaton. (a) automatic 2-thread chainstitch eyelet buttonholes; (b) automatic lockstitch buttonholes.

directly impacts the performance and appearance of the created seam. During sewing, the work piece moves along at a predetermined distance between successive penetrations of the needle (i.e. stitch length) using a feed mechanism (Fig. 6.20) whilst during the process the work piece is exposed to the influence of the feed dog and, presser foot pressure from above.

The pressure of the presser foot F_{pf}, which acts as the upper work piece layer, can be expressed as follows (Geršak, 2000, 2001):

$$F_{pf} = F_N = F_{sp} + F_g, \qquad [6.1]$$



6.18 Robotic sewing system for pocket setting.

where the spring-force F_{sp} is expressed as follows:

$$F_{sp} = k \cdot x \qquad [6.2]$$

and the force of gravity F_g:

$$F_g = m_{pf} \cdot g, \qquad [6.3]$$

where:

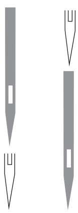
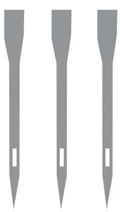
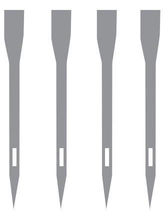
k spring-constant, in Nm^{-1},
m_{pf} mass of presser foot, in g.

Based on Equation [6.1], the friction-force between the upper work piece layer and the sewing presser foot F_{T3}, can be expressed as (Geršak, 2001):

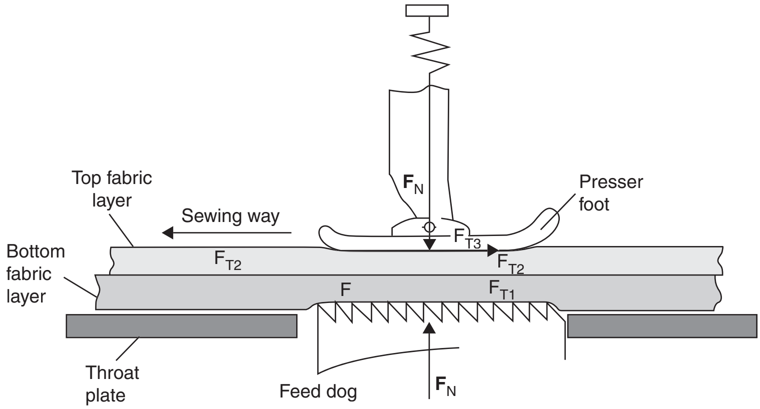
$$F_{T3} = F_{pf} \cdot \mu_3 = \left(F_{pf} + F_g\right) \cdot \mu_3 = \left(k \cdot x + m_{pf} \cdot g\right) \cdot \mu_3 \qquad [6.4]$$

and the friction-force between feed-dog teeth and the bottom work piece layer F_{T1} as:

$$F_{T1} = \left(F_{pf} + \Delta F_{g_w}\right) \cdot \mu_1 = \left(F_{pf} + F_g + \Delta F_{g_w}\right) \cdot \mu_1 = \left(k \cdot x + m_{pf} \cdot g + \Delta m_w \cdot g\right) \cdot \mu_1, \qquad [6.5]$$

Number of needles	Sewing machine type	Stitch class / type	
	Single-needle sewing machine	100 200 300 400 500	Chainstitches Single lockstitches, stitch type 209 Lockstitches Multi-tread chainstitches Overedge chainstitches
	Double-needle sewing machine	100 300 400 500 600	Chainstitch, stitch type 102 Lockstitches Multi-tread chainstitches Overedge chainstitches Covering chainstitches
	Double-needle sewing machines with the possibility of excluding one of the needles	300	Only for lockstitch, stitch type 301
	Three-needle sewing machine	300 400 600	Lockstitch, stitch type 303 Multi-tread chainstitch, stitch types 403, 407 Covering chainstitch, stitch types 604, 605
	Four-needle sewing machine	300 400 600	Lockstitch, stitch type 307 Multi-tread chainstitch, stitch type 410 Covering chainstitch, stitch types 606, 607, 608 and 609

6.19 Sewing machines sorted according to the number of sewing needles used.



6.20 Forces acting on the workpiece during its movement.
Symbols represent the following:

F	traction-force, that is, the force necessary to move the work piece, in cN,
F_N	normal-force, in cN,
F_{T1}	friction-force between the feed dog and the work piece's bottom layer, in cN,
F_{T2}	friction-force between the workpiece's upper and bottom layers, in cN,
F_{T3}	friction-force between the work piece's upper layer and the sewing presser foot, in cN.

where:

F_{pf}	pressure of the presser foot, in cN,
ΔF_{g_w}	the force of gravity of the work piece part between the presser foot and the feed dog, in cN,
μ_1	coefficient of friction between the teeth of the feed dog and the work piece's bottom layer,
μ_3	coefficient of friction between the work piece's upper layer and the presser foot,
Δm_w	the mass of the work piece part between the presser foot and the feed dog, in g.

The following conditions must be fulfilled for faultless movement of the work piece:

$$\text{I. condition: } F_{T2} - F_{T3} = 0, \tag{6.6}$$

$$\text{II. condition: } F > F_{T1} + F_{T2}. \tag{6.7}$$

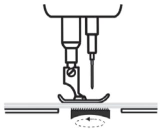
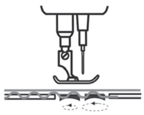
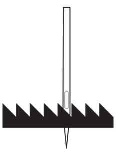
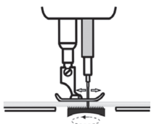
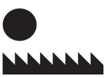
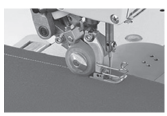
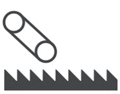
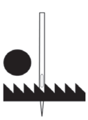
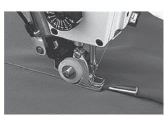
Because of the complex dynamic effect of the feed system on the work piece (e.g. feed dog with toothed surface, that acts on the work piece layers from below and pressure exerted by presser foot that acts from above), slippage can occur between work piece layers. This slippage between layers is hard to define, because of the complexity of its spatial and temporal structure. For example, in the case of drop feed, the work piece is moved from below in the direction of sewing over feed-dog teeth, whilst its movement is arrested from above by the activity of the presser foot. There is obviously a notable tendency for the bottom layer to move faster, while the top one tends to lag, while the work piece in the area where the seam has already been completed moves uniformly, as individual layers cannot move separately. As the feed dog acts intermittently on the work piece, the resulting movement is sliding and leveraging. Due to oscillations of the system 'feed dog/work piece/presser foot', the bond between individual work piece layers, caused by friction, is easily broken, and layers move separately. The result is a discrete, or un-coordinating, shift of work piece layers (Geršak, 2000, 2001).

All of this demonstrates that work piece layer feed is a complex process that has a direct influence on the quality of the created seam. In order to understand better the role of the work piece feed system and its impact on seam quality, a classification is given of sewing machines based on the type of feed mechanism employed, and its area of use, in Figs 6.21 and 6.22.

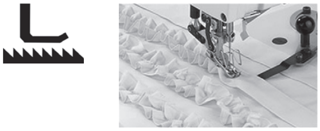
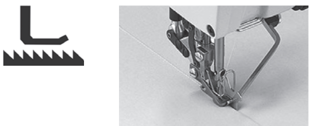
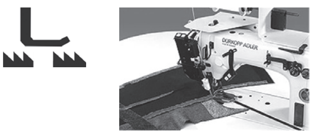
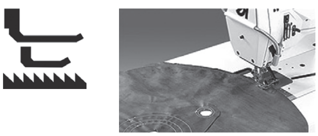
As well as the above-mentioned type of feed systems, it is also necessary to mention the teeth on the surface of the feed dog. The teeth on the feed dog's surface can be of different types and sizes (e.g.: coarse teeth, fine teeth, short toothpitch, long toothpitch, etc.) but they are generally slightly slanted towards the feeding direction. When sewing light- to medium-weight fabrics, a tooth pitch (with a distance from peak to peak of 1.3 to 1.6 mm) is normal. Fine-toothed feed dogs with a pitch of 1.0–1.25 mm can be used for very lightweight fabrics.

Movement of the work piece is important for two reasons (Geršak, 2000):

1. In achieving the objectives of good appearance and performance in seams, accurate and even stitch length is essential, along with fabric joins that are either smooth and unobtrusive or evenly eased or gathered, according to the requirements of fit and style.
2. Even and continuous work piece movement is a proper starting point for programming seam contour length, as well as for proper control of sewing machine operations.

Workpiece feed mechanism type	Area of use
Drop feed system  	Almost all of the basic sewing machines used to link work piece layers employ this mechanism, as there is no sliding between the layers. It is designed for a fast linking of light and medium-weight fabrics.
Differential bottom feed system  	This is intended for finishing smooth seams; the lower work piece ply can be gathered or stretched by adjusting the stroke of the feed dog in front of the needle or behind the needle. Special sewing machines for taping of armholes often use this type of mechanism.
Bottom and needle feed system  	This is used when producing smooth seams on medium-weight fabrics. The areas of usage include general sewing operations, sewing zippers, etc. As the work piece moves at the moment when the needle is in the fabric (synchronised movement of the needle and work piece layers), there cannot appear sliding between work piece layers.
Bottom and additional puller-feed system  	Used to ensure uniform seam quality, especially when sewing thin fabrics. It is appropriate for long seams, e.g. when sewing trousers, hemming shirts, etc. Additional puller-feed, in combination with a crank presser foot, prevents seam puckering. It is used on special sewing machines with a single, two, or more sewing needles.
Bottom and additional belt feed system  	Belt feed is performed using a smooth or toothed tape, generally in sewing work pieces of higher surface area. This mechanism ensures the making of smooth, long seams, primarily in joining fabrics sensitive to transport, such as silk poplin or plush.
Bottom, needle and additional puller feed system  	This is used in smooth sewing extremely thin and fine fabrics, such that have a strong tendency of seam puckering in sewing, e.g. for sewing plushes. The mechanism is often used in sewing edges, waistbands on skirts and/or trousers, as well as in decorative sewing on double-needle sewing machines.

6.21 Sewing machines with bottom, needle, and additional puller-feed system.

Work piece feed mechanism type	Area of use
Top and bottom feed system 	The mechanism for top work piece feed includes, apart from the pressure sewing point, a moving sewing point. When the pressure point does not move and is needed to secure the fabric, the moving point shifts the work piece together with the moving element. If the moving sewing point is active in front of the sewing needle, the upper work piece layer shirrs.
Top and bottom feed system 	If the sewing point is at the sewing needle (meaning the shift of the upper and bottom work piece layers are matched), a high-quality smooth seam is ensured in linking garment parts and sewing. This type of feed is specially recommended for smooth sewing of fabric sensitive to transport.
Top and differential bottom feed 	There is the opportunity to work in fullness, achieve shift-gree sewing or retard, or stretch the top or bottom layer. Used to the majority of seaming situations since it can be adjusted to feed each layer exactly as required in relation to the other. Special sewing machines for taping of armholes use this mechanism.
Alternating or variable top and bottom feed system 	Used to obtain a smooth seam in joining and sewing heavy-weight fabrics, such as fabrics for winter coats, blankets and bedspreads. It also offers: a) keeping the work piece upper layer and sewing the bottom layer in a tensioned state, b) shirring the upper workpiece layer.
Alternating or variable top, needle and bottom feed system 	Used to ensure high-quality smooth seams in joining heavy-weight fabrics, such as those for winter coats, blankets, bedspreads and leather for garments. It is valuable in the sewing of certain problem materials, especially those with tacky surfaces. In clothing industry it is generally used in decorative sewing.
Alternating or variable top and bottom differential feed system 	Offers high-quality smooth joining and controlled gathering (to work fullness) or stretching of the upper or bottom workpiece layer. This type of workpiece feed is intended for sewing heavy-weight fabrics, when a nice and smooth seam is required. It is used on special sewing machines, e.g. for setting in sleeves.

6.22 Mechanisms for top, bottom, and alternating workpiece feed systems and their areas of use.

6.8 Determining standard time

Determining the standard time[16] for a task is a prerequisite for the economic assessment of a particular process (Eversheim, 1989; Polajnar, 2006). It is done within the confines of process planning, employing empirical values, that is, previously used times. Determining standard time depends upon the time of performing (previous to manufacturing and at its completion), as well as the required precision when determining times. The total time necessary to perform a predetermined task is composed of the following elements (Anon., 2004; Ramsauer, 2011):

- t_{pc} preparation-completion time, needed to prepare the workplace for a particular activity or work and getting the workplace in order upon completion of the work;
- t_t technological time, that is, the time needed to perform particularly effective work, which results in a change of dimension, shape or structure for the material processed, regardless of whether the work is performed manually or by machine;
- t_p auxiliary time, that is, the time needed to complete auxiliary tasks, necessary to complete the technological task successfully; and
- t_d added time, needed to make up for the losses in the course of the working day, such as those for which the worker could not be blamed.

Technological and auxiliary time together constitute so-called normal time. A schematic presentation of the elements composing standard time can be seen in Fig. 6.23.

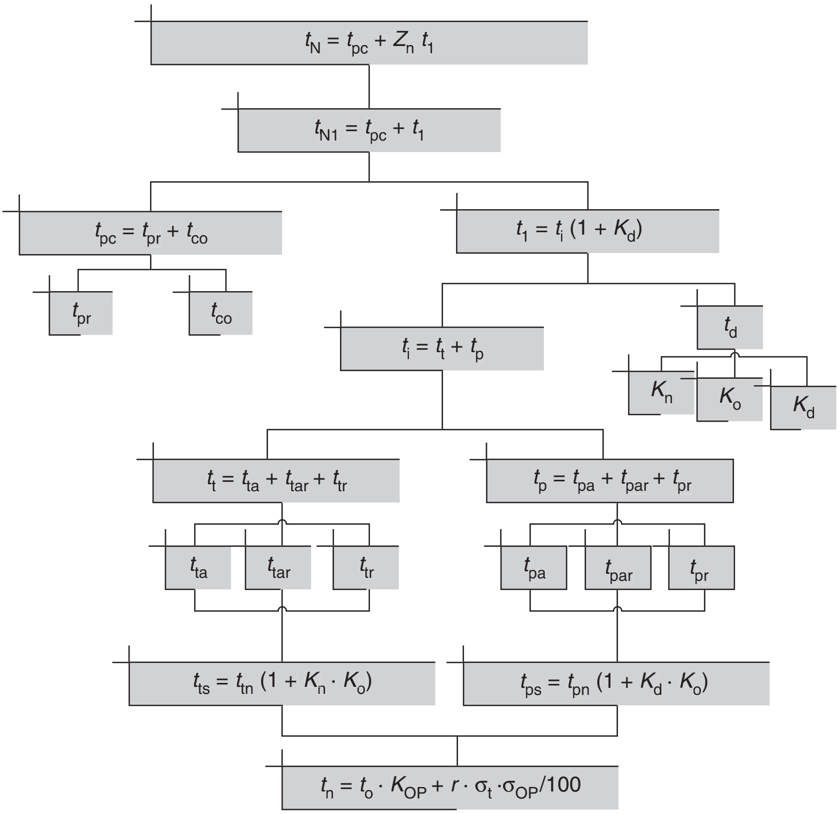
The time necessary to perform a task can be, according to the standard REFA,[17] determined on the basis of (Ramsauer, 2011):

a) measuring the actual time used, employing various methods, most often the method of measuring time using various instruments and devices; and
b) predetermined motion-time systems. The central idea of these systems is to decompose the work performed by a worker into standard movements and elemental tasks.

The most widely used predetermined motion-time systems in the clothing industry are the MTM (Methods Time Measurement), and the WF (Work

[16] **Standard time** is the time that an averagely skilled worker requires to perform, at conventional predetermined production conditions, using predetermined means of production and precisely defined method of work, at normal effort and fatigue, a precisely predetermined work (Polajnar, 2006).

[17] **REFA** (Reichsausschluss für Arbeitszeitermittlung) – A committee for determining manufacturing times, established in Berlon, Germany in 1924. It changed its name in 1936 into (Reichsausschluss für Arbeitsstudien) Board of work study, and in this way broadened its activities into the whole area of workstudy. Its headquarters are in Darmstadt, Germany, where the REFA institute is situated as well (Anon., 2004).



6.23 Elements composing standard time. Notes: t_N order (series) manufacture time; *Tpz* preparing-completion time; t_{pr} preparation time; t_{za} completion time; t_t technological time; t_{ta} machine technological time; t_{tar} machine-hand technological time; t_{tr} hand technological time; t_{pa} machine auxiliary time; t_{par} machine-hand auxiliary time; t_{pr} hand auxiliary time; t_p auxiliary time; t_{N1} time of manufacturing a single piece; t_n normal time (technological and auxiliary); t_1 standard for a single product or operation; t_i product manufacturing time (technological and auxiliary); Z_N number of pieces in a series; t_d added time (make up for all the losses and stops – expressed with the coefficients K_n, K_o, K_d); K_n coefficient of effort; K_o coefficient environmental impact; K_d coefficient of additional time; σ_{PR} standard deviation; K_{PR} coefficient of performance rating.

Factor) system. Predetermined motion-time systems have the advantage of elemental standard time systems in the sense that they can be used to develop standards and methods before a job exists.

Performance will vary with the skill and effort of the worker, so the observer must also estimate the worker's performance relative to some hypothetical average worker operating at a normal level of effort. This estimated performance is called the performance rating (Martinich, 1997), with values above 100% indicating greater than normal performance and values below 100% indicating less than normal performance. Performance ratings can be used to adjust the observed task time when establishing work standard.

The normal time t_n, otherwise known as basic time, can be expressed on the basis of the average value of the observed task time, considering coefficient of performance rating K_{PR}, in the following form (Ramsauer, 2011):

$$t_n = t_{\text{o}} \cdot K_{\text{PR}} + r \cdot \sigma_t \frac{\sigma_{\text{PR}}}{100}, \qquad [6.8]$$

where:

$$t_{\text{o}} = \frac{1}{N}\sum_{i=1}^{N} t_i, \qquad [6.9]$$

$$K_{\text{PR}} = \frac{\text{PR}}{100}, \qquad [6.10]$$

and where:

- K_{PR} coefficient of performance rating,
- PR performance rating,
- R correction coefficient between the time and performance rating,
- N number of observations – measurement of work,
- σ_t standard deviation of time values,
- σ_{PR} standard deviation of performance rating,
- t_{o} average value of the observed task times.

Normal time can be determined also using the total elemental task time or total predetermined task time (e.g. from MTM or WF analysis). The total elemental task time t_i, which is the sum of the individual technological t_t and auxiliary time t_p, which can be the combination of the total machine automatic t_a and the real times of the manual work t_s, can be expressed as:

$$t_i = t_t + t_p = t_{ta} + t_{ts} + t_{pa} + t_{ps} = t_{ta} + t_{tar} + t_{tr} + t_{pa} + t_{par} + t_{pr}, \qquad [6.11]$$

where:

- t_i normal time,
- t_t technological time,
- t_p auxiliary time,
- t_{ta} machine technological time,
- t_{ts} real technological time,
- t_{pa} machine auxiliary time,

t_{ps} real auxiliary time,
t_{tar} machine-hand technological time,
t_{tr} hand technological time,
t_{par} machine-hand auxiliary time,
t_{pr} hand auxiliary time.

Since the real time is influenced by the effort due to working with heavier objects or tools, uncomfortable body posture and monotony of work, when determining the real (i.e. the actual manufacturing) time t_s, coefficient of effort K_n, and coefficient environmental impact K_o must be taken into account. The real manufacturing time t_s can be expressed in the following form (Polajnar, 2006):

$$t_s = t_n \cdot (1 + K_n \cdot K_o), \qquad [6.12]$$

where:

K_n coefficient of effort and
K_o coefficient environmental impact.

If we accept that the real manufacturing time t_s is the technological t_{ts} and auxiliary t_{ps}, it can be expressed as:

$$t_{ts} = t_{tn} \cdot (1 + K_n \cdot K_o), \qquad [6.13]$$

$$t_{ps} = t_{pn} \cdot (1 + K_n \cdot K_o). \qquad [6.14]$$

The normal time t_i obtained, Expression [6.8] and/or Expression [6.11], is the basis on which standard time t_1 for a task or operation is calculated, which is obtained by taking into account the allowances, or so-called coefficient of additional time K_d,[18] and can be calculated as follows:

$$t_1 = t_i \cdot (1 + K_d). \qquad [6.15]$$

Standard time t_1 expresses the amount of time that can be used by an average operator, or means of work, to perform a particular working task or operation, working in accordance with predetermined work-flow, following the predetermined method of work and under the predetermined conditions of the environment. It is the time needed, on average by a skilled and properly qualified operator at a normal level of fatigue and effort, and under normal environmental conditions, to manufacture a single product or perform a single operation, and represents the so-called working standard.

[18] **Coefficient of additional time K_d** is time allowances for unavoidable delays (e.g., breakdowns), personal needs (restroom breaks), and worker fatigue, expressed as a fraction of total work time (Martinich, 1997).

Regarding the manner of expressing the amount of work, the standard can be:

- time standard, expressed as the units of time necessary to manufacture a single product or perform a single operation; or
- work standard, expressed as the number of products that should be manufactured in a shift or some other time unit.

Time standards have many important uses, although most companies use them primarily for planning. There are at least four uses for standard time data and work standards:

- Employee performance evaluation and compensation.
- Production and personnel scheduling.
- Product costing and pricing.
- Process design and capacity planning.

Work standards, which specify how much output a worker should be able to produce or how much time should be spent on certain activities, play an important role in the planning and operation of organisations (Martinich, 1997).

6.9 Planning manufacturing operations

A starting point when designing or redesigning a manufacturing activity is to perform an operations analysis – dividing the process into elemental tasks that are necessary for manufacturing a particular model. Each of these tasks represents a separate unit of work or operation. For each task, it is necessary to estimate how long it would take to perform it. This estimate may be based on experimentation or established work standards.

An operation is a part of the work or technological process dealing with the processing of a predetermined area of a material or product, as a work piece, using a particular machine or tool. The sequence of operation in a working, that is, technological process, is the sequence during which a fabric or a body gradually changes its shape or properties, from a 2D fabric into the final 3D product – an article of clothing. The work process involved describes the work that is supposed to be performed, throughout a particular organisational flow, by an operator or a group of operators at a workplace. The sequence of a work process matches the sequence of a workplace.

The operation plan, as the central document during the planning of manufacturing activities, consists of a general informative part, that is, model name, designation, short description, probably a model drawing, and data such as work order designation, who placed the order, date, etc., as well as a list of all the necessary operations to perform whilst manufacturing the product. It also includes defining the sequence of operations within the proposed manufacturing process, the necessary equipment, the level of complexity of the planned work, and the standard time. The scope of selection when determining operations is limited by process planning, and the available machines and other processing equipment. The operation plan should be carried out separately for cutting, sewing and finishing, and used as the central document for planning. It is directly connected with other planning documents and with production management. An example of a part of the operation plan for sewing a man's jacket can be seen in Fig. 6.24. The standard time within an operation plan can be expressed in seconds, minutes or hours, and is determined by employing methods for determining standards, that is, a selected method of work study.

Recapitulation of time should be done based on the finished technological operation plan. Recapitulation of time can be done for:

- processing equipment, that is, particular machine groups of the same type (e.g. for all basic or special sewing machines);
- individual technological processes, that is, cutting, sewing, and finishing; and
- total manufacturing time.

Times for particular technological processes during clothing manufacturing are recapitulated by employing the following equations:

$$t_{\text{cu}} = \sum_{i=1}^{n} t_{\text{cu}_i}, \qquad [6.16]$$

$$t_{\text{sw}} = \sum_{i=1}^{m} t_{\text{sw}_i}, \qquad [6.17]$$

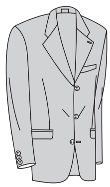
$$t_{\text{fin}} = \sum_{i=1}^{k} t_{\text{fin}_i}, \qquad [6.18]$$

whilst the total manufacturing time by product unit is calculated as:

$$t_1 = t_{\text{cu}} + t_{\text{sw}} + t_{\text{fin}}, \qquad [6.19]$$

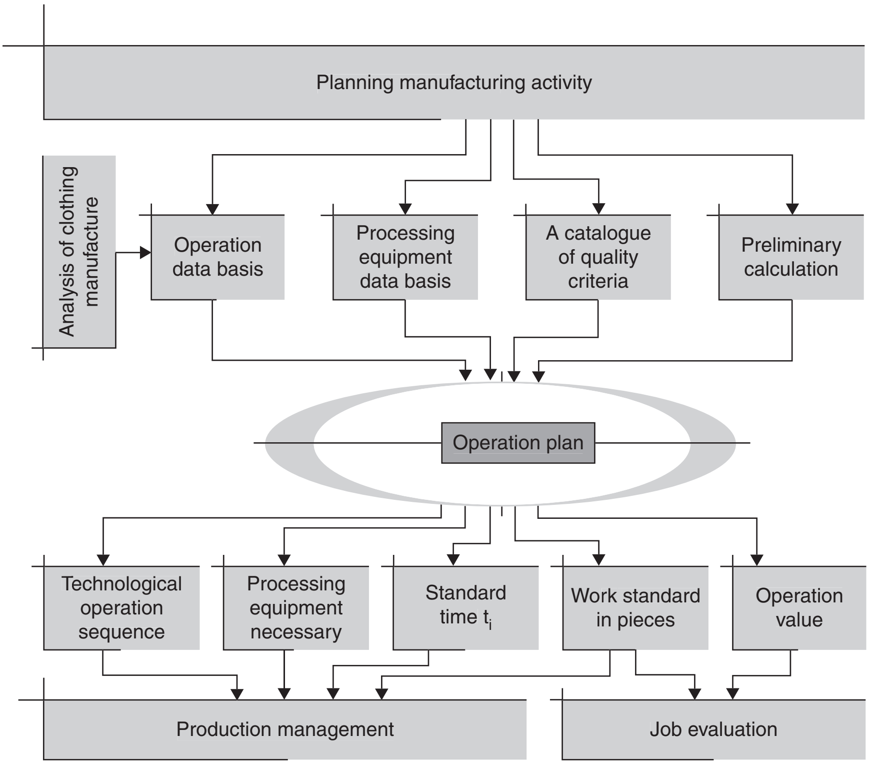
where:

t_{cu} cutting operation time, in minutes,
t_{sw} sewing-operation time, in minutes,
t_{fin} finishing operation time, in minutes,
t_{cu_i} the time for the ith cutting operation ($i = 1, 2, 3, \ldots, n$), in minutes,
t_{sw_i} the time for the i_{th} sewing operation ($i = 1, 2, 3, \ldots, m$), in minutes,
t_{fin_i} the time for the ith finishing operation ($i = 1, 2, 3, \ldots, k$), in minutes.

Plan for sewing operation			Page: 1
Product type: men's jacket	Model name: Artemis		Season: P0303
	Collection: K2-12		Model signature: 235
	Production order		DN0606/12
	Raw material composition		100 % wool
	Notes		
	Date	3. 3. 2012	
	Prepared by		

No.	Technological operation	Seam/stitch class and type	Equipment class and type	Standard time t1/min
01S	Prepare bundle for sewing: pocket flaps, breast welt, collars		working board	2.80
02S	Sewing pocket flap and trimming	1.01.01/301	sewing automaton	0.39
03S	Shaping and pressing the flap		Veit Varioset	0.47
07S	Assembling upper collar and half-moon fabric shape	1.01.01/401	special sewing machine	0.25
08S	Assembling top and bottom collar	1.01.01/301	basic sewing machine	0.25
13S	Sewing front lining to facing. Sew sew side panel seams	1.01.01/301	basic sewing machine	1.30
14S	Ironing the seams flat		Veit Varioset	0,95
15S	Making 4 piped pockets on the lining	5.17.01 (301.301)	sewing automaton for pocket piping	1.10
35S	Sewing a breast dart	6.05.01/301	sewing automaton	0.55
37S	Sewing side panel to the front part	1.0.01/301	sewing automaton	0.65
38S	Making central back seam	1.0.01/301	sewing automaton	0.45
39S	Securing breastwelt pocket bar with zig-zag stitch	5.30.01/304	special sewing machine	0.80
85S	Sewing 3 buttons		sewing automaton	0.75
86S	Making (wrapping) button shank		sewing automaton	0.35
87S	Additional ironing and quality control		Ironing machine	2.20
			Total time $t_{sw} = \Sigma$	**90.36**

6.24 A part of the sewing-operation plan for sewing men's jackets.



6.25 Operation plan functions.

Manufacturing time values obtained from time recapitulation are used in the further data calculation necessary during planning manufacturing activity, but also in the process of capacity and term planning, when preparing calculations, when calculating costs, in production control, investment planning and the acquisition of economically viable equipment, calculation of wages, prices, etc. A schematic presentation of the operation plan's role can be seen in Fig. 6.25.

Standard manufacturing time for a particular operation or product can be used to determine work duration or the time necessary to fulfil an order (manufacture a series) t_N, using the following equation:

$$t_N = t_{pc} + K_N \cdot t_1, \qquad [6.20]$$

where:

t_{pc} preparation-completion time,
t_1 standard time per product unit,
K_N number of product units in the order.

Preparation-completion time is the time necessary for the preparation prior to manufacture and to prepare the workplace, as well as to get the workplace into the initial state necessary for commencing the work. It should be noted that preparation-completion time appears only once, regardless of whether a single article is produced or the whole series.

6.10 Planning clothing assembly

Planning processes and operations deal with the processing of particular garment parts, whilst clothing assembly is planned separately, that is, as a process for determining the logical inclusions of particular constituent elements into a functional form – an article of clothing. Planning clothing assembly should be treated as a multi-stage procedure during production planning. The starting point of clothing-assembly planning is a structural problem, namely how to produce a predetermined product from an individual component, or so-called building elements, giving it a functional form. From the point of view of activities, clothing assembly includes:

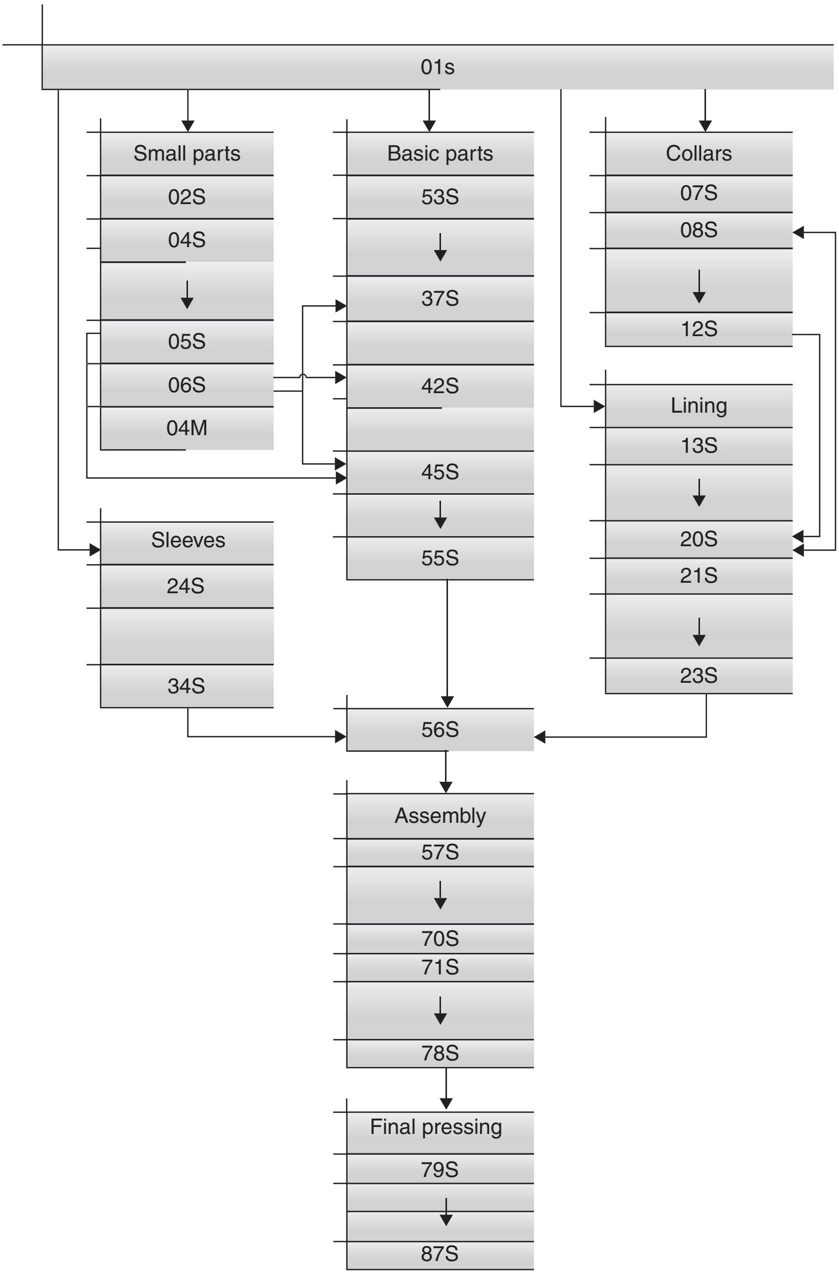
- planning the assembly line; and
- planning the assembly's process flow.

When planning assembly process flow it is necessary to know the relationship between particular assembly tasks, so as to ensure that the product is made from individual sets following a predetermined sequence. Planning assembly activities, determined in the form of a so-called assembly plan, is based on a sewing-operation plan, knowing the production lines, and knowing the systems involved in the technological process.

The purpose of a clothing-assembly plan is to define the logical and rational spatial distribution of operations, as related to assembly and pre-assembly lines, so as to ensure a continuous material-flow from one workplace to the other throughout the production line, without back-flow. Individual operations should be reasonably divided into the main assembly line and a number of auxiliary lines, or so-called pre-assembly lines, such as:

- pre-assembly line B (for smaller parts),
- pre-assembly line C (for collars),
- pre-assembly line D (for sleeves),
- pre-assembly line E (for lining), etc.,

so that individual auxiliary lines are included within the main assembly line, thus ensuring a logical flow of the sewing process. Figure 6.26 shows an example of an operational flowchart for men's jackets with an illustration of the main assembly line and a logical incorporation of individual auxiliary (pre-assembly) lines. An operational flowchart, that includes



6.26 Operational flowchart for men's jackets.

material-flow, is a starting point for installing equipment in the sewing room, having in mind the previously determined capacity, and a prepared sewing process plan.

6.11 Planning a process system for manufacturing operations

A prepared plan of technological operations and those predetermined activities included in clothing assembly are a sound basis for planning a process system. A process system is, according to REFA, defined as a system used for realising production orders, which involves people and the production means (Anon., 2004). Modern clothing factories use five basic process systems. These are:

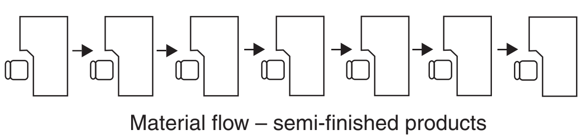
1. Line process system
2. Phase process system
3. Combined process system
4. Flexible process system and
5. Cellular system.

6.11.1 Line process system

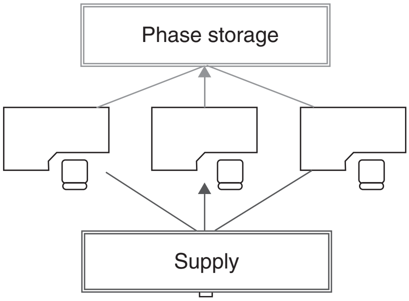
The line system, also known as the line process, is based on a production line, where operations regarding the working group's rhythm follow a chronological sequence and each other, as shown in Fig. 6.27. Processing stages in continuous flow processes are so tightly connected that it is essential for processing times to be the same at each production stage. All the operations are performed simultaneously, but with each at its own workplace. In the linear process system, the production process is uninterrupted from one workplace to the other, and no phase storage is necessary. Despite the variety of linear system models, this process cannot be recommended for the clothing industry and is seldom used (probably only in knitted garment manufacture).

6.11.2 Phase process system

The phase process system is a system in which particular operations are, due to manufacturing process complexity, joined into functional groups; the so-called sections or phases, as shown in Fig. 6.28. This manufacturing process is usually divided into phases that follow one another. Depending on the



6.27 Line process system.



6.28 Phase process system.

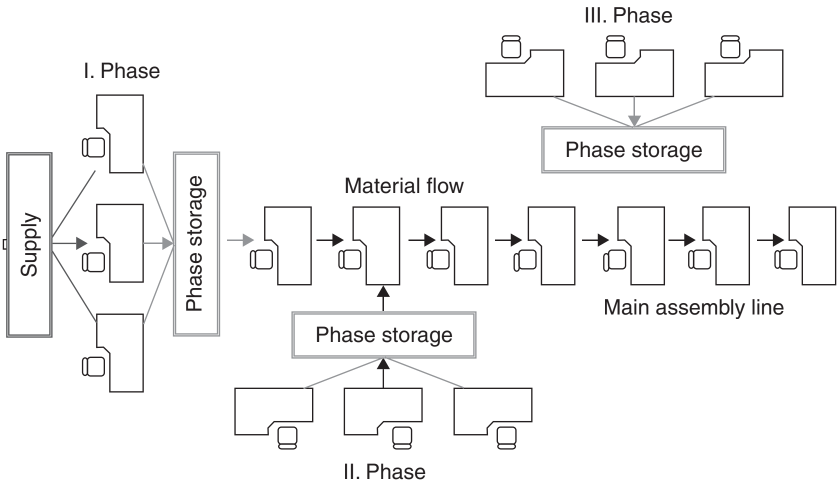
activities involved, they can be pre-assembly or assembly phases. Pre-assembly phases are designed primarily for the manufacture of individual smaller units (smaller parts during the manufacture of jackets, trousers, collars, sleeves, lining, etc.). It is not usually used as an independent system but in combination with a line one, and is characterised by phase storage.

6.11.3 Combined process system

The combined process system is a combination of line and section systems, utilising the advantages of both, thus enabling an uninterrupted manufacturing process flow, and ensuring rational material-flow. Depending on the nature of the work and operational structure, the process of manufacturing individual smaller garment units or sets of garments in the forms of pre-assembly parts, is organised during the section part of the system, whilst assembly activities (activities involving the logical joining of individual components, the so-called building elements, into a functional form – an article of clothing – see Fig. 6.26), are performed on the main assembly line, following the principles of the line system, as shown in Fig. 6.29. The combined system offers, based on adequate planning, a balanced production process flow and uninterrupted material-flow from one workplace to the next, making it the most appropriate system for the clothing industry. It includes more operators who perform a single, or two or more operations.

6.11.4 Flexible process system

The flexible process system is a system offering high process adaptability for various models and their associated material-flow requirements, or providing workplaces with adequate materials and/or work pieces. These systems are able to adapt to a wide diversity of models, both from the point of view



6.29 Combined process system.

of operational type and structure, and the selection of adequate equipment. Their adaptability can be attributed to:

- modern phase work piece transport systems ensuring that workplaces are directly supplied, regardless of their spatial distribution within the plant; and
- implementation of proper transport vehicles and flexible stands that offer a direct supply to individual workplaces employing manual transport.

Direct workplace supply, either employing the mechanical means of phase-transport or appropriate transport vehicles, is flexible enough to eliminate the need for adapting processing equipment to each model, regardless of the chronology of the operation's flow. This adaptation is only usually done at more distinct changes in the model or fabric type.

6.11.5 Cellular manufacturing system

The cell-system, also known under the acronym Cellular Manufacturing (CM), can be defined as an application of group technology (GT), which denotes an organisational method based on a group technology concept, where a particular organisational unit, also called a cell, constitutes an independent technological whole for manufacturing a component or a group of work pieces, which disposes with all the necessary processing equipment and auxiliaries (Burbidge, 1991). The origins of this concept can be traced to the 1980s, when J. L. Burbidge (1975) in his book, *The Introduction of Group Technology*, introduced the concept of cell-technology.

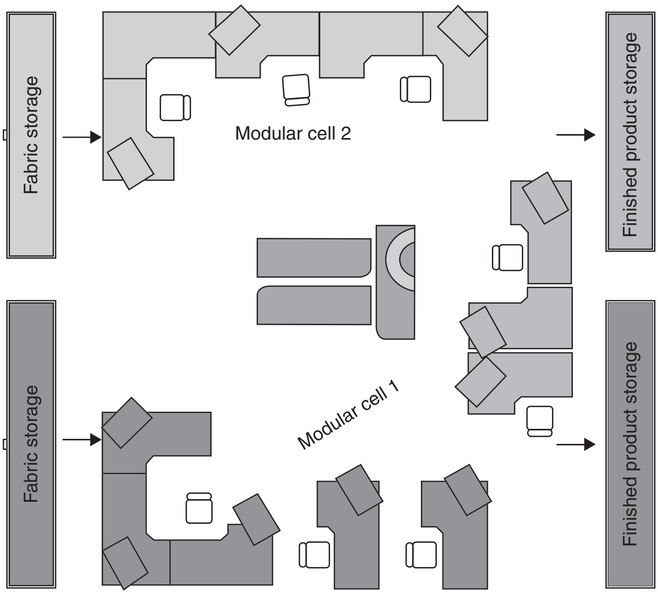
The importance of CM systems has grown over the course of the past 20 years or so. Investigations indicate that between 43% and 53% of companies in the USA and the UK use this system (Johnson and Wemmerlov, 2004), and this percentage grows to 73% for companies employing 100 or more people (Fraser and Harris, 2007). The 1990s witnessed attempts to adapt clothing manufacturing processes to new strategies, known under the acronyms Quick Response System (QRS) and Just in Time (JIT) which introduced the cell-system into the clothing industry as well. At the beginning, modules were developed for manufacturing simple and less demanding garment models. However, practice proved that joining modules could result in efficient production of the most demanding models.

The concept of a CM system, where individual modules constitute an independent technological cell, differs from the other systems in that:

(a) a modular-based cell constitutes an independent technological unit, which integrates the entire processing equipment necessary for manufacturing a particular model (the operator often has three machines at his/her workplace, or even more: a basic sewing machine, a special sewing machine, and a machine for phase ironing);
(b) the operator has to master all the equipment and perform a number of operations (because of the model's diversity and clothing manufacturing technology he/she has to be skilled in performing up to 20 or even more technological operations); and
(c) individual cells are independent of the operators and the resources used during the manufacture (the same operator or the same equipment can be involved in one or more cells, as seen in Fig. 6.30).

Overhead phase-transport or conventional transport vehicles and flexible stands can be used within each cell, which ensures the system's high flexibility. A modular unit or cell, composed of a smaller group of operators (8 to 10 or 12 people at the most) is planned as a self-organising and self-learning unit, with special emphasis on teamwork and direct operator participation during the manufacturing process. This unit usually has no direct leader and all the operators are in charge of manufacturing process organisation, eliminating stoppages, auto-control, and control after each phase.

The cellular concept is characterised by high-adaptability to changes in manufacture, as well as by its high-efficiency and product quality. It is also distinguishable by its humane work and high degree of operator satisfaction. Despite excellent results, the cellular concept is seldom encountered in Slovenia (it is often treated as a trial system, intended for the manufacture of models in small series, prototypes, and collections). However, practical experience has shown some success for this concept in Slovenia as well. A



6.30 CM system as independent technological units.

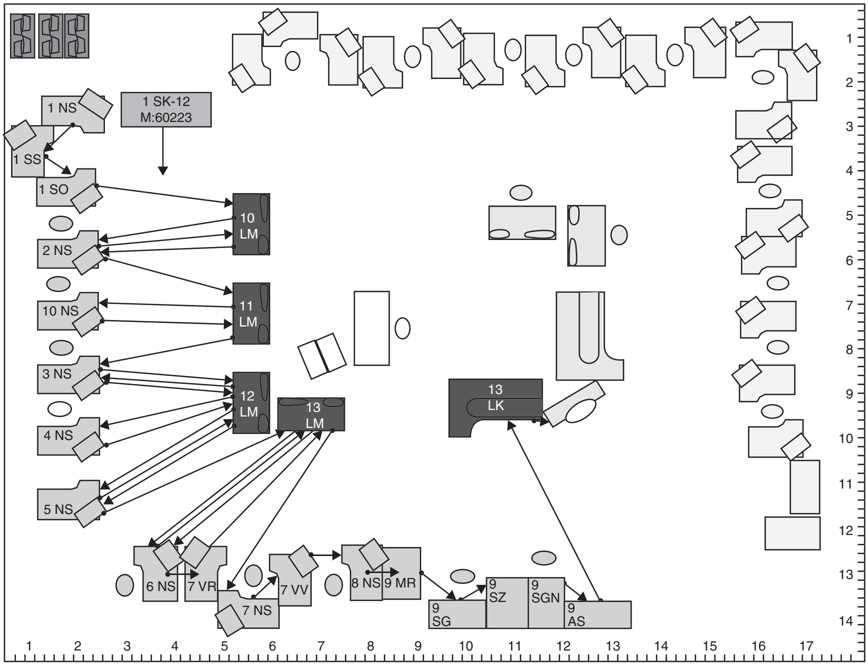
good example of cell-based production can be seen in Escada's daughter companies Elos – Escada, Ltd., and Epas, Ltd., at Gornja Radgona. The layout of the equipment for one of the manufacturing cells designed within the Epas company can be seen in Fig. 6.31.

6.12 Planning clothing manufacturing processes

Planning clothing manufacturing processes plays an important role during process management. Its task is to form a so-called process plan, based on an understanding of operations, necessary equipment, and associated standard time. This plan is supposed to ensure a continued process flow and, related to this, a continued material-flow from one workplace to the next, which is a basic prerequisite for an efficient and high-quality clothing manufacturing process.

This means that the expert designing the plan should study, in detail, the implementation of adequate methods and accessories when performing high-quality, flexible, and cost-effective processes, and determine the time necessary for performing them, based on workplace or operator utilisation levels.

The process plan, as a basic document during production and phase-transport management, is designed on the basis of an operation plan and



6.31 Layout of designed cell as an independent technological unit, in the sewing room of the company Epas, Ltd.

a clothing assembly plan, whilst special attention should be paid to the following.

- Workplace or operator utilisation levels regarding the complexities of the operations and operator's skills.
- Functionally joining operations (if operator utilisation is insufficient) regarding workplaces, meaning that, at a particular workplace, operations similar in manner of performance should be organised.
- Workplace design.

Clothing manufacturing process planning, which results in so-called process plans (e.g. cutting, sewing, and finishing), is based on the information that has its origins in:

- standard time (as determined within the operation plan);
- daily working hours; and
- production unit or working group capacity (number of operators and available processing equipment).

By respecting the nature of work and the specific characteristics of particular clothing manufacturing processes, process planning is performed separately for cutting, sewing and finishing. Provided the organisation of work allows it, planning the processes of cutting and finishing can be done for more than one product or model, meaning that the plan for the cutting and/or finishing processes involves more models, whilst planning the sewing process must be done for each model separately, or for each production unit/cell.

The completed process plan includes:

- the necessary number of operators;
- production unit or working group capacity;
- operator capacity;
- working group rhythm;
- workplace or operator utilisation; and
- the necessary amount of processing equipment.

Planning the necessary number of operators is done using daily capacity:

$$D = \frac{C_d \cdot t_1}{t_{dn}}, \qquad [6.21]$$

where:

D necessary number of operators,
C_d daily capacity in pieces,
t_1 manufacturing time per product unit, in minutes,
t_{dn} daily working time, in minutes.

The expression [6.21] can be used to calculate daily capacity C_d:

$$C_d = \frac{D \cdot t_{dn}}{t_1}. \qquad [6.22]$$

Production unit or working group daily capacity can be determined using the known values of the working group rhythm R_{ds}, using the expression:

$$C_d = \frac{t_{dn}}{R_{\mathrm{ds}}}. \qquad [6.23]$$

Processing equipment planning is determined on the basis of the necessary equipment number N_{TO}, which is calculated using the general expression:

$$N_{\mathrm{TO}} = \frac{C_d \cdot t_{\mathrm{TO}}}{t_{dn}}, \qquad [6.24]$$

while the necessary amount of particular processing equipment is calculated using the following expressions:

$$N_{\text{PS}} = \frac{C_d \cdot t_{\text{PS}}}{t_{dn}}, \tag{6.25}$$

$$N_{\text{KrA}} = \frac{C_d \cdot t_{\text{KrA}}}{t_{dn}}, \tag{6.26}$$

$$N_{\text{BS}} = \frac{C_d \cdot t_{\text{BS}}}{t_{dn}}, \tag{6.27}$$

$$N_{\text{SS}} = \frac{C_d \cdot t_{\text{SS}}}{t_{dn}}, \tag{6.28}$$

$$N_{\text{SA}} = \frac{C_d \cdot t_{\text{SA}}}{t_{dn}}, \tag{6.29}$$

$$N_{\text{LS}} = \frac{C_d \cdot t_{\text{LS}}}{t_{dn}}, \tag{6.30}$$

where:

- N_{TO} necessary number of processing equipment, in pieces,
- N_{PS} necessary number of laying machines, in pieces,
- t_{PS} the time for performing laying operations on laying machines, in minutes,
- N_{KrA} necessary number of automatic cutting machines, in pieces,
- t_{KrA} the time for performing layer cutting operations using automatic cutting machines, in minutes,
- N_{BS} necessary number of basic sewing machines, in pieces,
- t_{BS} the time for performing sewing operations on basic sewing machines, in minutes,
- N_{SS} necessary number of special sewing machines, in pieces,
- t_{SS} the time for performing sewing operations on special sewing machines, in minutes,
- N_{SA} necessary number of sewing automata, in pieces,
- t_{SA} the time for performing sewing operations on sewing automata, in minutes,
- N_{LS} necessary number of ironing machines, in pieces,
- t_{LS} the time for performing ironing operations on ironing machines in minutes.

The working group rhythm R_{ds}, defined as the time planned for a work piece to remain at a workplace, is calculated as follows:

$$R_{\mathrm{ds}} = \frac{t_1}{D} \qquad [6.31]$$

or from the daily capacity:

$$R_{\mathrm{ds}} = \frac{t_{\mathrm{dn}}}{C_d}, \qquad [6.32]$$

where:

R_{ds} working group rhythm, in minutes,
t_1 manufacturing time by product unit, in minutes,
D number of operators,
C_d daily capacity, in pieces,
t_{dn} daily working time, in minutes.

The clothing industry uses working group rhythm R_{ds} to calculate the workplace utilisation level S_{dm} or operator utilisation level S_D; this level being expressed as follows:

$$S_{\mathrm{dm}} = \frac{t_1}{R_{\mathrm{ds}}} \times 100, \qquad [6.33]$$

where:

S_{dm} workplace utilisation, in %,
t_1 the time for performing a technological operation, in minutes.

Workplace utilisation may be the same as operator utilisation, or may differ from it, depending on the operation's duration and daily capacity. When performing a particular operation it is often connected with predetermined equipment, the workplace utilisation level being determined by the duration of the operation and daily capacity. For example, if the workplace utilisation level is $S_{\mathrm{dm}} < 100\%$, the operator is assigned an additional technological operation (or more operations), so as to reach an approximately 100% level of operator utilisation ($S_D \cong 100\%$).

In order to plan real process flow properly, it is necessary to know the workplace utilisation level and operator efficiency.[19] When planning a process, special attention should be paid to the functional combination of operations (in case of insufficient operator utilisation level), the aim being to

[19] **Efficiency** – defined by the number of products the operator produces in a unit of time. An operator's working efficiency is measured by the amount of work he/she performs in a unit of time. It has a tendency of varying in the course of working hours.

perform operations at the same workplace whenever possible. Additionally, operators should be trained in the high-quality performance of more than one operation, so that a change in operations does not have a detrimental effect on the working group's rhythm, that is, on reaching the norm.[20]

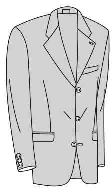
Operations differ according to performance, processing equipment, and duration, which means that it is necessary during process planning to ensure a uniform operator utilisation level. This should be around 100% as, regardless of the normal conditions of the manufacturing process, individual efficiency may vary due to differences in the abilities of individual operators and their degree of fatigue. Some variations can be allowed, provided we are familiar with the complexity of the operation, the production capacity of the equipment used, and the individual abilities and skills of the operators. Figure 6.32 shows an example of part of the process planning (this document presents plans for the sewing process of a man's jacket).

The completed plan contains the calculations for individual work pieces and operator utilisation levels, the necessary number of operators and the necessary amount of processing equipment. The process plan is used as a basis for recapitulating the overall number of necessary operators and processing equipment pieces. A specification is made of the necessary equipment for the processes of cutting, setting, sewing and finishing, using the plans for individual processes. The specification of the necessary equipment for a particular production order can be obtained from the processing equipment recapitulation. Figure 6.33 shows an example of the equipment recapitulation needed to perform the process of sewing men's jackets.

The process plan, designed separately for cutting, sewing and finishing processes, is used as a central document during production, phase control, and management, and is a foundation for equipment lay-up. Its function as a central document is to ensure uninterrupted material-flow from one workplace to the next, and it is connected with the other documents included in production planning and control, as shown in Fig. 6.34.

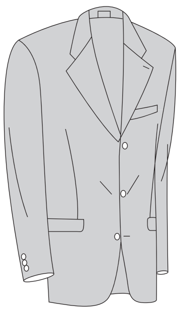
Proper production system design enables the determination of material, energy and information flow, as well as fulfilling numerous other requirements, which ensures the basic process functions as a system (Geršak *et al.*, 1994). In this way, for example, adequate workplaces are determined based on material-flow and available working areas. An area intended for a working process is composed of the working area, preparation area, transport routes, and areas for phase storage. A workplace working area should be properly designed so as to ensure an optimal effect for the

[20] **Norm** is the time necessary for an averagely skilled operator to perform, under normal manufacturing conditions, using predetermined equipment, in a precisely determined manner, at normal effort and fatigue, precisely predetermined work.

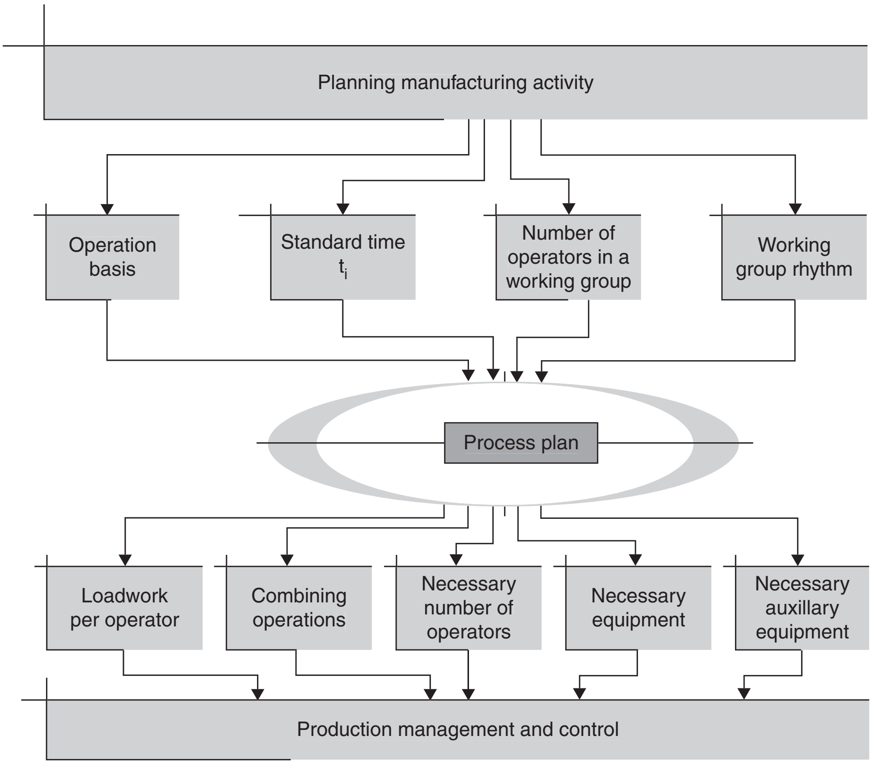
Sewing process plan		Page: 1
Product type: men's jacket	Model name: Artemis	Season: P0303
	Collection: K2-12	Cut designation: 235
	Production order	DN0606/12
	Production unit designation	PE08
	Production unit daily capacity	300 pieces
	Manufacturing time Number of operators	90.36 minutes 56
	Working group rhythm R_{ds}	1.61 minutes
	Deta	3. 3. 2012
	Prepared by:	

Workplace mark	Technological operation		Time t_i/min	Workplace utilisation level S_{dm} /%	Number of operators required	Operator utilisation level SD/%	Processing equipment	
	Mark	Name					Name and designation	Necessary number
1	2	3	4	5	6	7	8	9
	01S	Preparing layers for sewing, pocket flaps, breast welt, collars	2.80	173.91			working table	2
	58S	Mark bottom collar in the neckline	0.60	37.27			working table	1
DM01-2				211.18	2	105.59		3
	07S	Sewing front lining onto front edge and sewing side parts onto front ones	1,30	80.74			BS 275	1
	21S	Joining lining on the back, side and shoulder, sewing lining onto the collar	2.05	127.33			BS 275	1
DM27-28				208,07	2	104,03		2
	50S	Sewing side seams	1.13	70.18			BS 275	1
	52S	Joining jacket on the shoulder	0.80	49.69			BS 275	1
	60J	Sew peak lapel with template	0.90	55.90			BS 272	1
	61S	Sewing front edge and trimming	2.10	130.43			BS 272	2
DM43-45				306.20	3	102,07		5
Recapitulation			**90.36**		**56**			**73**

6.32 A part of the sewing process plan for a men's jacket.

Recapitulation of sewing process equipment				Page: 1	
Product type: men's jacket		Model name: Artemis		Season: P0303	
		Collection: K2–12		Cut designation: 235	
		Production order		DN0606/12	
		Production unit designation		PE08	
		Production unit daily capacity		300 pieces	
		Date		3. 3. 2012	
		Prepared by:			
Number	Design.*	Equipment name	Manufacturer	Equipment	Planned number
				Class and type	
01	TO-BS08	basic sewing machine	Dürkopp Adler	272 140042 / E21	3
02	TO-BS04	basic sewing machine	Dürkopp Adler	272 140042 / E53	5
03	TO-BS02	basic sewing machine	Dürkopp Adler	271 140042 / E27	2
04	TO-BS05	basic sewing machine	Dürkopp Adler	219 124176 / E114	2
05	TO-BS19	basic sewing machine	Dürkopp Adler	219 115156	1
16	TO-SS08	special sewing machine	Pfaff	3822–1/44	1
17	TO-SS03	special sewing machine	Dürkopp Adler	550–12–12	1
18	TO-SS12	special sewing machine	Dürkopp Adler	55016–6/E6	2
22	TO-SA12	sewing automaton	Dürkopp Adler	742–115–1-1	1
23	TO-SA04	sewing automaton	Recce	S 2000	1
33	TO-LS07	special ironing press	Hoffman	HKR	1
Total					73

6.33 Summary of the equipment needed for sewing a men's jacket. *Designation of equipment concerns the code from technical specification in Processing equipment description (6.6).



6.34 Process plan functions.

system's man-machine system interface (Geršak, 1986, 1989, 17; Kroemer and Grandjean, 1999).

Various technological studies have shown that around 30% of total clothing manufacturing time relates to cutting, sewing and finishing, whilst 70% involves working-process preparation, phase-transport, the picking-up, positioning, measuring, checking, control and laying-off of the work piece. The machine time-share and equipment utilisation level can be increased through better and more rational workplace design, and the implementation of proper work methods (Geršak, 1986; Žunič Lojen and Geršak, 1991; Bezjak and Geršak, 1996; Kobayashi, 2003).

Workplace design is a set of activities that should be performed systematically from the points of view of:

(a) technological workplace design, by the selection of proper equipment and designing methods of work that represent the most important areas;

(b) technical workplace design, which includes designing workplaces from equipment and accessories selection (various guides, apparatuses and/or auxiliary devices) to equipment selection regarding the operation type to be performed;
(c) ergonomic workplace design, based on ergonomic principles, being a starting point for more humane working conditions.

Planning a rational process requires a workplace to be designed in such a way as to enable the operator to perform his/her work efficiently and at normal levels of fatigue. It can be done providing the workplace is (Kroemer and Grandjean, 1999):

- adapted in shape and dimensions to the human body and musculoskeletal system flexibility;
- designed so that the operator assumes the posture required using the minimum amount of effort; and
- provided with equipment matching physiological and psychological properties of the human body.

Apart from a properly designed workplace, adequate and optimal layout of equipment within the production system plays an important role, as it impacts work piece, information and energy-flow.

Properly selected material-flow is one of the basic requirements for an adequately functioning working system, and for ensuring adequate starting values (Kobayashi, 2003). Proper processing equipment layout enhances material-flow, improves working efficiency, and the efficiency of the equipment used. Security precautions at work should also be respected and measures taken to prevent accidents and injuries at work (Council Regulation (EC) No 1112/2005).

6.13 Conclusions

Planning clothing manufacturing is a very complex process, characterised by the globalisation (as a rapid rate of change in both technology and the marketplace) that has created an enormous strain on existing planning clothing manufacturing and consequently on production management. According to the complexity of clothing manufacturing processes, planning manufacturing activities plays an important role from the point of view of quality as well as regarding the question of how to be competitive within the market. The large diversity of models and fabrics used, the numerous manufacturing operations, and the growing requirements regarding quality, and uniqueness of clothing, as well as the requirement to shorten manufacturing and delivery times and reduce costs, requires extra efficient, flexible and quality planning of all manufacturing activities.

To achieve these objectives we have presented in this chapter the process of clothing production planning based on a systematic approach to the analysis of clothing manufacturing and selection of appropriate processing equipment, work study and work methods, as the basis for the design of individual work operations. Special focus has been given to the breakdown of work processes and methods of work, because the choice of adequate work methods is of extreme importance for planning and optimising sewing, primarily due to the high level of complexity regarding the process and also because of general requirements when performing sewing operations. A properly selected method of work offers the possibility of sewing longer segments of seam contours without interruption, which is reflected in higher seam quality, as a more uniform sewing process flow ensures lower oscillations in the stitching speed and shortens the manufacturing time.

Based on this knowledge, special attention has been given to the planning of manufacturing operations and clothing assembly, and preparation of key documents such as the operation plan and clothing assembly plan, respectively the operational flowchart, and planning a rational system for manufacturing. Finally, the clothing manufacturing planning process has been presented. Its task is to form a so-called process plan, which is supposed to ensure a continued process flow and a continued material-flow, which is a basic prerequisite for an efficient and high-quality clothing manufacturing process.

6.14 References

Albrecht, W., Fuchs, H., Kittelmann, W. (2003), *Nonwoven Fabrics: Raw Materials, Manufacture, Applications, Characteristics, Testing Processes*. Weinheim, Wiley-VCH Verlag GmbH & Co. KGaA.

Anon. (2004), *REFA Handbook: Work System and Work Design*, Part 1, Darmstadt, REFA Verband für Arbeitsgestaltung, Betriebsorganisation und Unternehmensentwicklung e.V.

Bezjak, Z. and Geršak, J. (1996), *Analysis of Operator Load as a Function of Workplace Design* (in Slovenian), Book of proceedings, Garment engineering ‘96, Maribor, University of Maribor, Faculty of Mechanical Engineering, 138–148.

Burbidge, G. M. (1975), *The Introduction of Group Technology*, New York, Wiley.

Burbidge, G. M. (1991), ‘Production flow analysis for planning group technology’, *Journal of Operations Management*, **10** (1), 5–27.

Council Regulation (EC) No 1112/2005 of 24 June 2005 amending Regulation (EC) No 2062/94 establishing a European Agency for Safety and Health at Work, *Official Journal*, L **184**, 15.7.2005, p. 5–9.

Eversheim, W. (1989), *Organisation in der Produktionstechnik, Arbeitsvorbereitung*, Band 3, Dϋsseldorf, VDI Verlag GmbH.

Eversheim, W. (1996), *Organisation in der Produktionstechnik, Grundlagen,* Dϋsseldorf, VDI Verlag GmbH.

Flood, G. (1989), ‘Ultrasonic bonding of nonwovens’, *Tappi Journal*, **May**, 165–170.

Fraser, K. and Harris, H. (2007), 'Team-based cellular manufacturing', *Journal of Manufacturing Technology Management*, **18** (6), 714–730.

Geršak, J. (1987), *Workplace Optimisation from the Point of View of Optimal Sewing Methods* (in Slovenian) (PORS-12: DO PIK Maribor), Report for the year 1986, Maribor, Faculty of Engineering.

Geršak, J. (1989), *Workplace Optimisation in Garment Industry* (in Slovenian) (PORS-12: 2708/795–89), for DO Labod, TOZD Delta Ptuj), Report for the year 1989, Maribor, Faculty of Engineering.

Geršak, J., Stjepanovič, Z. and Podlesek, J. (1994), *Work Preparation and Information Flow in Clothing Manufacture Process*, Entwicklungspotential in Energie-, Material- und Informationsfluss, DWI Reports, 113, Aachen, Deutsches Wollforschungsinstitut an der Technischen Hochschule Aachen, 457–465.

Geršak, J. (2000), *The Influence of Sewing Processing Parameters on Fabric Feeding*, Proceedings of the 29th Textile Research Symposium at Mt. Fuji, Shizuoka, 141–152.

Geršak, J. (2001), 'Directions of sewing technique and clothing engineering development' (in Croatian), *Tekstil*, **50** (5), 221–229.

Gownder, J. P. (2011), 'Mass customization is (finally) the future of products', Published on Forrester Blogs (http://blogs.forrester.com). Available from: http://blogs.forrester.com/jp_gownder/11–04–15-mass_customization_is_finally_the_future_of_products [Accessed 15 March 2012].

Gownder, J. P. and Corbett, A. (2011), It's time for mass-customized clothing and apparel products', Published on Forrester Blogs (http://blogs.forrester.com). Available from: http://blog.treehouselogic.com/2011/07/05/forrester-its-time-for-mass-customized-clothing-and-apparel-products/ [Accessed 15 March 2012].

Hänsch, D. (2007), *Fields of Application for Textiles and Clothing*, European Textile and Clothing Supply Chain Linking Conference, Ronse, 23 October.

Hatch, K. L. (1993), *Textile Science.* New York, West Publishing Company.

ISO 4915:1981 Textiles – Stitch types – Classification and terminology, First edition.

ISO 4916:1982 Textiles – Seam types – Classification and terminology, First edition.

Johnson, D. J. and Wemmerlov, U. (2004), 'Why does cell implementation stop? Factors influencing cell penetration in manufacturing plants', *Production and Operations Management*, **13** (3), 272–289.

Jones, I. (2005), 'Improving productivity and quality with laser seaming of fabrics', *Technical Textiles International*, **14** (3), 35–38.

Kehry, S. (2007), 'Modernes Fügen von technischen Textilien', *Technische Textilien – Technical Textiles*, **50** (2), 162–163.

Kobayashi, I. (2003), *20 Keys* (in Slovenian, translated by Petra Paušer), Ljubljana, Lisac & Lisac d. o. o.

Kroemer, K. H. E. and Grandjean, E. (1999), *Adapting Work to Man* (in Croatian), Textbook of ergonomics, Croatian professional editor Ilija Manenica (translated by Susan Shaw-Manenica), Jastrebarsko, Edition Slap.

Lee, S.-E. and Chen, J.C. (2000), 'Mass-customization methodology for an apparel industry with a future', *Journal of Industrial Technology*, **16** (1), 1–8.

Liekweg, D., Rademacher, K., Deseyve, A. and Hopf, H. (1983), *Optimale Nähmethoden für die Konfektion von Maschenwaren*, Sigmaringen, Technischer Beratungsdienst an der Fachhochschule.

Lim, H., Istook, C. L. and Cassill, N.L. (2009), 'Advanced mass customization in apparel', *Journal of Textile and Apparel, Technology and Management*, **6** (1), 1–16.

Martinich, J. S. (1997), *Production and Operations Management – An Applied Modern Approach,* New York, John Wiley & Sons Inc.

Pine, B. J., II (1993), *Mass customization*. Boston, Harvard Business School Press.

Polajnar, A. (2006), *Workstudy* (in Slovenian), Second edition, Maribor, University of Maribor, Faculty of Mechanical Engineering.

Ramsauer, C. (2011), *Industrial Engineering*, 8th Edition, Graz, Graz University of technology, Institute for industrial management and innovation Research.

Schierbaum, W. (1982), *Bekleidungs-Lexikon*, 2. erweiterte Auflage, Berlin, Fachverlag Schiele & Schön GmbH.

Volino, P. and Magnenat-Thalmann, N. (2000), *Virtual Clothing – Theory and Practice*, Berlin and Heidelberg, Springer-verlag GmbH & Co. K.

Žunič Lojen, D. and Geršak, J. (1991), 'Workplace design in garment industry' (in Slovenian), *Tekstilec*, **34** (2–3), 79–84.

Žunič Lojen, D. and Geršak, J. (1994), 'Sewing operation structure as dependent upon the method of work' (in Croatian), *Tekstil*, **43** (12), 611–671.

7
Clothing production management

DOI: 10.1533/9780857097835.209

Abstract: This chapter reviews planning, scheduling, monitoring and control activities. The chapter then discusses costs in production, including calculations. Finally, control in production planning and management is discussed.

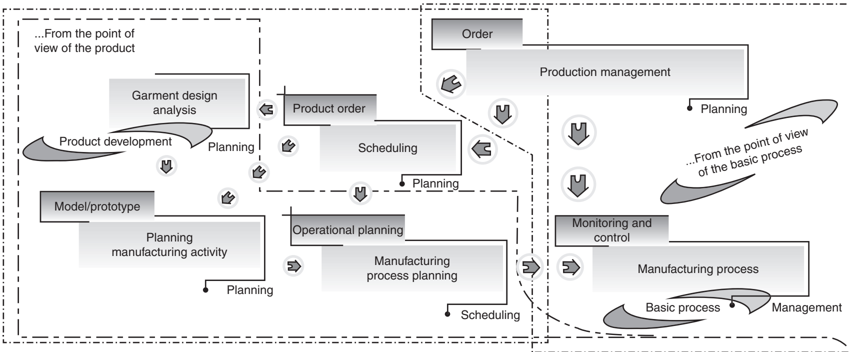
Key words: clothing manufacture, production management, planning, scheduling, monitoring, control, cost, calculation, controlling.

7.1 Introduction

Production management encompasses the activities of planning and managing manufacture and assembly, from the points of view of capacity planning and scheduling, as well as production monitoring and control. Production management includes all those activities and actions necessary to realise an order, and is based on the results of adequate production planning. The relationship between target sales volumes, on the one hand, and available capacity, on the other, vary significantly from month to month. It is thus necessary to match target sale volumes with available production capacity. Achieving a match requires an operational production plan. The basic aims of operational plans are to plan production flow whilst minimising costs with rational, continuous utilisation of the workforce, materials and processing equipment. It is essential to ensure a smooth production process flow which dispatches products on time (Chase *et al*., 2005).

Production management includes the precise coordination of all activities involved in monitoring the manufacturing process. Coordination is important to ensure that all manufacturing capacities are utilised, whilst monitoring of the manufacturing process is needed to maintain this coordination and ensure that the manufacturing capacities are utilised as planned. Thus, production management dictates '*What*', '*When*' and '*Where*' to produce, and includes the following:

- production planning,
- timing of manufacturing activities or scheduling and
- production monitoring, which includes production capacity and sales and procurement.



7.1 Production management's role and function.

The '*When*' element represents the crux of all planning, and the timescale dictates which activities have to be performed and when they should be completed, while the '*What*' and '*Where*' elements require coordination along the time axis to ensure that they are available when required. This is the most important planning function, because seasons have fixed starting and finishing terms and exact timing is necessary to fully exploit the selling periods available.

Besides planning functions, the aims of production management are:

- high capacity utilisation,
- short material flow-time,
- optimal capital utilisation with low operating and workforce costs,
- lower stocks in storage and high flexibility.

Production management involves the following important activities:

- determining the necessary production capacities,
- production planning,
- timing of manufacturing activities,
- compiling technical data for planning calculations,
- planning basic and auxiliary materials, and their procurement,
- issuing work orders,
- planning fabrics for cutting,
- production monitoring.

The key role from among the above activities is issuing work or production orders, because these encompass most of the technical documents necessary for organising and managing a production process efficiently. Work orders should be prepared with care and are issued for the processes of cutting, sewing and finishing, and include also those documents necessary for taking materials from the storeroom and dispatching finished products into appropriate storage. From the point of view of the work as a whole, it is salient that production management should be organised to direct and coordinate a production process efficiently. Figure 7.1 describes the role and function of production management. Data flow and data processing play key roles in the process, thus making automatic data processing unavoidable.

7.2 Determining production capacity needs

Production capacity is the ability of an enterprise or production unit to produce a certain number of products in a certain time. Production capacity is determined by the capacity of manufacturing equipment, and can be defined by:

- the type and quantity of processing equipment,
- the number of operators,
- the type and number of products or models to be produced,
- the market.

Production capacity is calculated on the basis of:

- the fund of working hours,
- number of operators,
- daily working time,
- time to manufacture a single product,
- productivity level.

The fund of working hours can be calculated per year or per day. The fund of working hours per year t_{Fy} can be calculated as follows (Collins and Glendinning, 2004; Anon., 2011a; Rogale *et al*., 2011):

$$t_{\mathrm{Fy}} = t_{\mathrm{d}} \cdot D \cdot N_{\mathrm{y}}, \qquad [7.1]$$

whilst the fund of working hours per day t_{Fd}, can be expressed as:

$$t_{\mathrm{Fd}} = \frac{t_{\mathrm{Fy}}}{N_{\mathrm{y}}} = t_{\mathrm{d}} \cdot D, \qquad [7.2]$$

where:

t_{d} daily working time,
D number of operators,
N_{y} number of working days in a year.

Daily production capacity C_d can be determined from daily working time as follows:

$$C_d = \frac{t_{\mathrm{Fd}}}{t_1} = \frac{t_{\mathrm{d}} \cdot D}{t_1}. \qquad [7.3]$$

Production capacity C_y may be calculated by:

$$C_{\mathrm{y}_i} = \frac{t_{\mathrm{Fy}}}{t_1} = \frac{t_{\mathrm{d}} \cdot D \cdot N_{\mathrm{y}}}{t_1}, \qquad [7.4]$$

where t_1 is the manufacturing time for a single product, expressed in minutes. The necessary number of operators D can be calculated from capacity, using the following equation:

$$D = \frac{C_{\mathrm{y}} \cdot t_1}{N_{\mathrm{y}_i} \cdot t_{\mathrm{d}}}. \qquad [7.5]$$

To calculate yearly or daily capacity, various products, each of which may have different manufacturing times, must be taken into account. The general equation above is therefore corrected using the factor $K_i/100$, where K_i means the shares of particular models as a percentage. In this way, individual partial capacities can be calculated, whilst the yearly partial-production capacity C_{y_i} can be expressed as:

$$C_{y_i} = \frac{t_{\mathrm{d}} \cdot D \cdot N_{\mathrm{y}}}{t_1} \cdot \frac{K_i}{100}. \qquad [7.6]$$

The necessary partial number of operators D_i can be expressed as:

$$D_i = \frac{C_{\mathrm{y}} \cdot t_1}{N_{\mathrm{y}} \cdot t_{\mathrm{d}}}. \qquad [7.7]$$

Daily partial-production capacity C_{d_i} is calculated using the equation:

$$C_{d_i} = \frac{D \cdot t_{\mathrm{d}}}{t_1} \cdot \frac{K_i}{100}, \qquad [7.8]$$

whilst the necessary daily partial number of operators D_{d_i} is defined by the following equation:

$$D_{d_i} = \frac{C_{d_i} \cdot t_1}{t_{\mathrm{d}}}. \qquad [7.9]$$

The target yearly production capacity is determined using the sum of the partial capacities:

$$C_y = \sum_{i=1}^{n} C_{y_i}, \qquad [7.10]$$

and the overall number of necessary operators is determined from the sum of the partial numbers of operators, using the equation:

$$D = \sum_{i=1}^{n} D_i. \qquad [7.11]$$

The number of working days required for an order can be calculated according to the following expression, using the known production capacity:

$$N_d = \frac{K_N}{C_d} = \frac{K_N \cdot t_1}{D \cdot t_\mathrm{d}} \qquad [7.12]$$

where:

D number of operators,
K_N number of products in the production order, in pieces,
N_d the necessary number of working days to realise the order.

7.3 Production planning

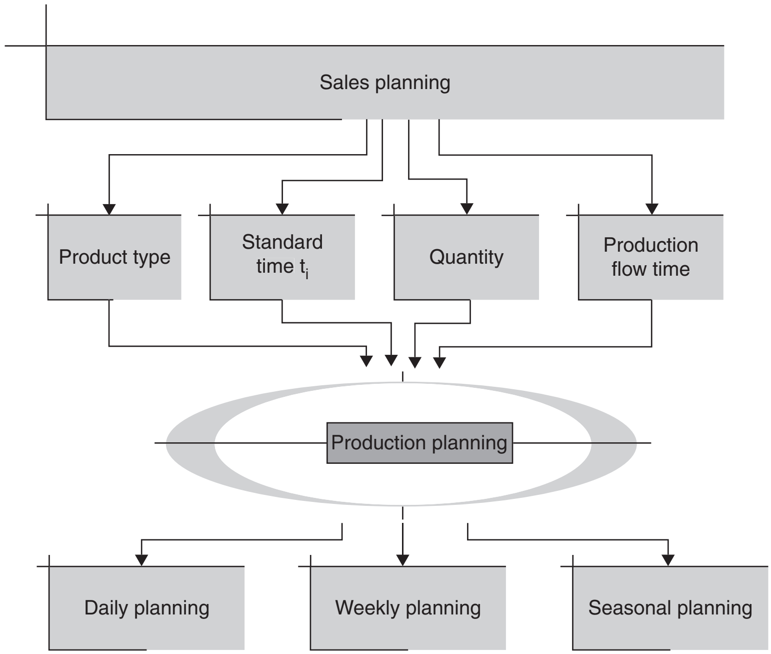
Production planning is linked with sales planning, following product planning by type, quantity, and schedules over a planned period. Production planning can take into account days, weeks, or the whole season, see Fig. 7.2. This type of production planning depends on an accurate and properly balanced production plan, determining what will be produced, the amount to be produced, and the time needed to produce it.

7.3.1 Daily production planning

Daily production planning depends on three factors:

1. productivity level,
2. effective manufacturing time for a single product,
3. daily planned capacity.

Productivity as a measure of worker efficiency (productivity level S_p) is calculated by:



7.2 Production planning.

$$S_p = \frac{t_1}{t_{ef}} \cdot 100, \qquad [7.13]$$

where:

S_p % productivity level,
t_1 manufacturing time for a single product in minutes,
t_{ef} effective manufacturing time in minutes,

whilst the effective time t_{ef} is determined from the productivity level, using the equation:

$$t_{ef} = \frac{t_1}{S_p} \cdot 100. \qquad [7.14]$$

Daily planned production capacity C_{dp} can be calculated as follows:

$$C_{dp} = \frac{D \cdot t_d}{t_{ef}}. \qquad [7.15]$$

Daily effective working time $t_{d_{ef}}$ for a shift is determined on the basis of an 8 h working time t_d, and by taking into account the following:

t_{lb}	Lunch break	30 min
t_{pn}	Time for physiological needs	5 min
t_{pe}	Planned break in the form of physical exercise	2×5 min
t_c	Time necessary to clean the machine	5 min

Daily effective working time per shift can be expressed as:

$$t_{d_{ef}} = t_d - \left(t_{lb} + t_{pn} + t_{pe} + t_c\right), \quad [7.16]$$

where:

t_d daily working time in minutes,
$t_{d_{ef}}$ daily effective working time in minutes.

7.3.2 Weekly production planning

Weekly production planning is made for one or more weeks, and depends on the:

- number of products or models,
- time necessary to manufacture a single product or model,
- number of operators,
- flow-time or throughput-time.

The available number of working days for each work order is the starting point for calculating weekly capacity. The number of working days N_d required for a weekly plan is calculated using Equation [7.12]. A weekly capacity plan involves differing products and models. This means it is important to know the flow-time or through put-time. Flow-time consists in: time spent preparing and processing; the waiting time before and after processing; control and transport times. It is the time required for a product to pass through a manufacturing process (i.e. through cutting, sewing and finishing). Flow-time t_{pc} is composed of three partial flow-times:

$$t_{pc} = t_{pck} + t_{pcs} + t_{pcf}, \quad [7.17]$$

where:

t_{pck} cutting flow-time in minutes,
t_{pcs} sewing flow-time in minutes,
t_{pcf} finishing flow-time in minutes.

Individual partial manufacturing flow-times are defined as follows:

$$t_{\text{pck}} = \frac{K_N}{C_{\text{dk}}} + t_{\text{pk}}, \qquad [7.18]$$

$$t_{\text{pcs}} = \frac{K_N}{C_{\text{ds}}} + t_{\text{ps}}, \qquad [7.19]$$

$$t_{\text{pc}_\text{f}} = \frac{K_N}{C_{\text{df}}} + t_{\text{pf}}, \qquad [7.20]$$

where:

K_N number of products in the work order, in pieces,
C_{dk} cutting room daily capacity, in pieces,
C_{ds} sewing room daily capacity, in pieces,
C_{df} finishing daily capacity, in pieces,
t_{pk}, t_{ps} and t_{pf} time necessary for preparation, phase-transport and phase-storage in the cutting room, sewing room, and finishing.

There are three methods of workflow, from the point of view of an individual processing schedule:

1. In a consecutive workflow, individual manufacturing processes follow one another without interruption. It is characterised by the longest flow-time. Flow-time in this method is expressed as follows:

$$t_{\text{pc}_{\text{zap}}} = t_{\text{pck}} + t_{\text{pcs}} + t_{\text{pcf}} = \frac{K_N}{C_{d_k}} + t_{\text{pk}} + \frac{K_N}{C_{d_s}} + t_{\text{ps}} + \frac{K_N}{C_{d_f}} + t_{\text{pf}}. \qquad [7.21]$$

2. In an overlapping workflow, the activity of a planned process is performed, or initiated, whilst the activities of the previous process are still going on. Flow-time is reduced, and can be expressed as:

$$t_{\text{pc}_{\text{dpr}}} = t_{\text{pc}_{\text{k-zac}}} + t_{\text{pcf}} + t_{\text{pcf}} = t_{\text{pCk-zac}} + \frac{K_N}{C_{d_s}} + t_{\text{pS}} + \frac{K_N}{C_{d_f}} + t_{\text{pf}}, \qquad [7.22]$$

where $t_{\text{pck-zac}}$ is the initial cutting flow-time.

3. In a parallel or simultaneous workflow, an activity belonging to one process is performed simultaneously with the activities of the following process. Flow-time is significantly reduced and can be calculated as follows:

(a)

ID	Process/activity name	Start	Finish	Duration
1	Technological process of cutting	14.5.2012	16.5.2012	3d
2	Technological process of sewing	17.5.2012	25.5.212	7d
3	Technological process of finishing	28.5.2012	29.52012	2d

(b)

ID	Process/activity name	Start	Finish	Duration
1	Technological process of cutting	14.5.2012	16.5.2012	3d
2	Technological process of sewing	16.5.2012	24.5.2012	7d
3	Technological process of finishing	25.5.2012	28.5.2012	2d

(c)

ID	Process/activity name	Start	Finish	Duration
1	Technological process of cutting	14.5.2012	16.5.2012	3d
2	Technological process of sewing	16.5.2012	24.5.2012	7d
3	Technological process of finishing	24.5.2012	25.5.2012	2d

7.3 Methods of scheduling production flows in the clothing industry.
(a) Consecutive method of production flow.
(b) Overlapping method of production flow.
(c) Parallel or simultaneous method of production flow.

$$t_{\mathrm{pc}_{\mathrm{vzp}}} = t_{\mathrm{pc}_{\mathrm{k\text{-}zac}}} + t_{\mathrm{pcs}} + t_{\mathrm{pcf\text{-}zak}} = t_{\mathrm{pCk\text{-}zac}} + \frac{K_N}{C_{d_s}} + t_{\mathrm{pS}} + t_{\mathrm{pC}_{\mathrm{f\text{-}zak}}}, \qquad [7.23]$$

where $t_{\mathrm{pcf\text{-}zak}}$ is the final processing time.

Planning flow-time plays an important role in production planning and management. A schematic representation of the methods of scheduling individual processing within clothing manufacture is given in the Gantt chart in Fig. 7.3.

7.3.3 Seasonal production planning

Demand for garments is primarily seasonal, since most customers decide to buy spring or summer garments from April to mid-June, and autumn or winter garments from September to the beginning of December. This calls for adequate production planning. Seasonal production planning depends on the number of collections and generally includes two seasons:

1. Spring – Summer,
2. Autumn – Winter.

Product capacity for a particular season is determined on the basis of daily- or yearly-planned capacities. The following aspects of preparation play an important part in seasonal production planning:

- seasonal plan for collection preparation,
- seasonal plan for collection manufacture,
- seasonal manufacturing plan.

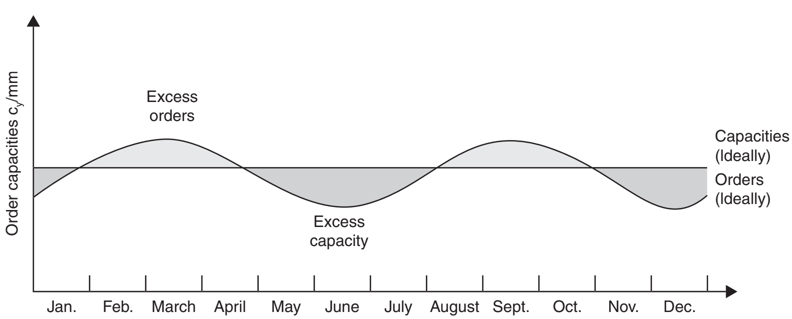
These plans include the time needed to prepare or manufacture the collection, or to manufacture the required garments. These plans define how long collection preparation takes, collection manufacturing and production flow, as well as requirements for equipment, materials and workers. When assigning orders, those generating higher profit should have preference, being more favourable for company development. The following factors in production should be taken into account during production planning (Geršak and Pevec, 1993):

- short procurement terms,
- short innovative time for the preparation of new products or collections,
- higher quality,
- parallel production by different flexible working groups for various sizes, for example, manufacturing the collection and adapting the production programme to market demands and market abilities.

A well-planned production schedule has an important impact on the quality of the manufacturing process to be performed.

7.4 Production scheduling

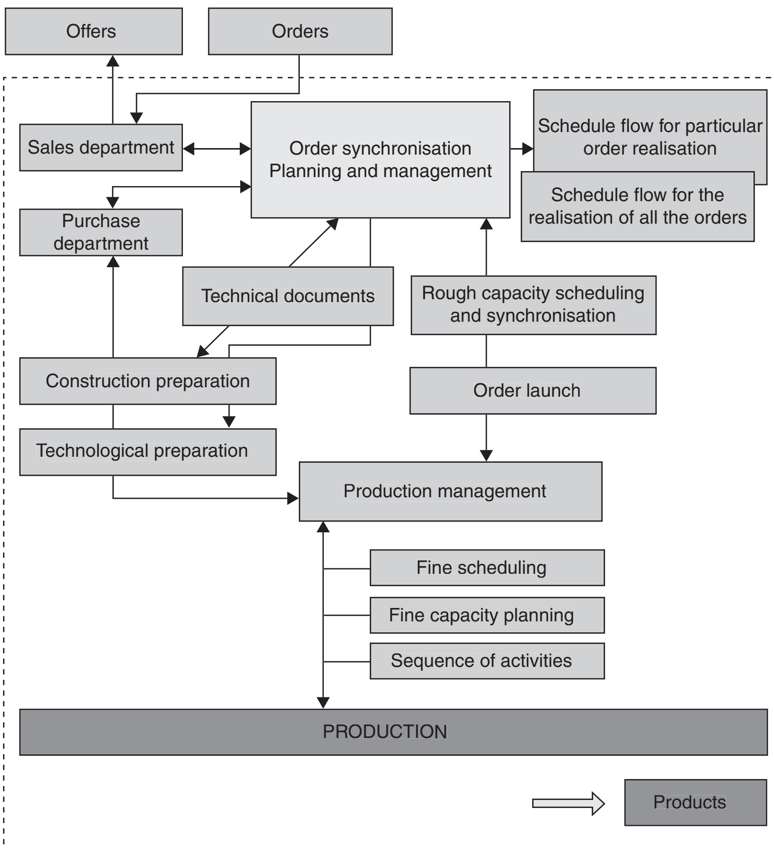
Due to problems of seasonal discrepancies in orders, production orders are condensed into certain periods. This is particularly true for some geographical areas, as seasons vary around the world. Currently, whilst the ability to produce is uniformly distributed on the one hand, on the other schedules for orders are unevenly distributed, as presented in Fig. 7.4. However, this



7.4 Discrepancies between orders and capacities.

problem could be solved with the global application of proper marketing solutions. The problem of seasonal discrepancies could be solved through market dispersion and efficient and dynamic production capacity planning. Capacity planning is a key element in production planning and management, and is associated with preparing time schedules (i.e. dynamic schedules of production process flow).

Synchronising orders is especially important. Synchronisation includes coordinating manufacturing by order and activities at various levels of production planning and management. Monitoring the realisation of received orders is essential in order to synchronise them. All the information needed for a proper process flow should be complete, and obtained on time. Figure 7.5 shows a model of order-planning and management, including those requirements at different levels of activity in order to achieve synchronisation. Rough planning of order-flow is also important and serves to improve order realisation and enhance flexibility in responding to problems from both within and without the company (Eversheim, 1989).



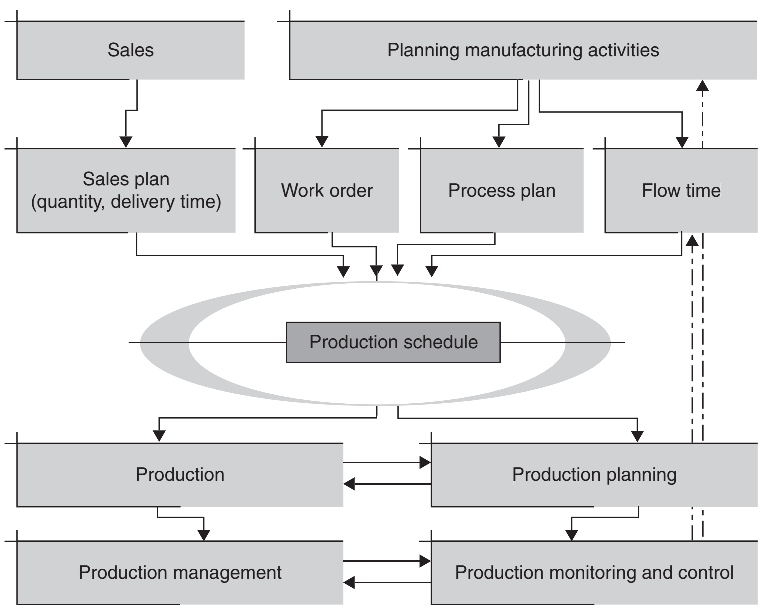
7.5 A model of activities in the field of order synchronisation.

Schedule plans, designed for different time periods, indicate when to perform activities so that the order deadline is reached. These plans include schedules, sequence, and synchronisation of activities (Kerzner, 1998; Anon., 2011a). Schedule plans are the most important parts of operational planning, and are used as a basis for:

- making auxiliary plans, such as: plans for required labour; material (determining the deadlines for procurement and preparation of materials); processing equipment, and; financial means
- organisational measures, such as: production management; performing work on time; production control; and time-related work control.

Activity scheduling is probably the single most important tool for determining how best to integrate company resources towards synergy. The inclusion of a production schedule within the production system and management can be seen in Fig. 7.6. Various techniques are used when forming schedule plans (Kerzner, 1998) including:

- The Gantogram technique (a histogram),
- milestone charts,
- network scheduling techniques.



7.6 Integration of production schedule within the production management process.

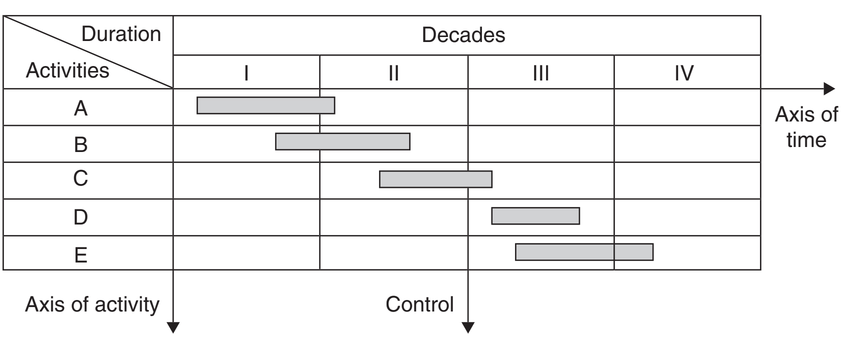
Selecting a scheduling technique depends on the technological complexity of a process and associated activities. In more complex processes the network technique is used, whilst for technologically stable processes Gantt's technique is preferable.

7.4.1 The Gantogram (histogram) technique for schedule planning

Gantt's technique is the oldest technique for schedule planning. It is named after its founder Henry L. Gantt, and is based on the use of a coordinate system in which the horizontal axis represents time whilst the vertical axis represents activity. See Fig. 7.7. Gantt's technique can also be used when preparing dynamic auxiliary plans, such as a:

- workforce plan,
- necessary processing equipment plan,
- plan of materials,
- financial means plan.

In these instances, activities are not entered onto the vertical axis. Instead, workforce, processing equipment, main materials, or financial means are entered. Although Gantt's technique is considered to be the most widely used graphic presentation of schedule plans, it is unable to present the relationships between activities, or to determine critical paths. A Gantt chart can also be created, in modified form, using network planning techniques. For this purpose, the chart can be used for presenting reserve times for activities and critical paths. However, as before, no interdependent activities can be presented in this way.



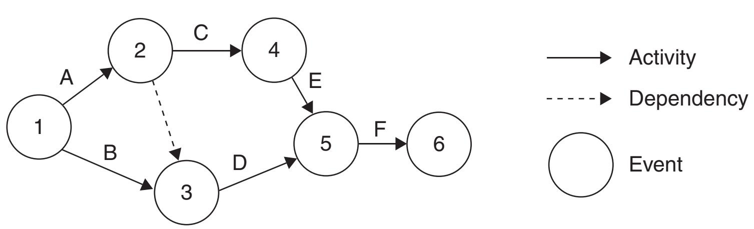
7.7 A schematic representation of an original Gantt chart form.

7.4.2 Network techniques for schedule planning

Network scheduling techniques originated in the USA and offer distinct improvements. They allow identification of those activities on which the whole process flow depends. These are known as critical activities, and their sequence represents the critical path of a process. The most common approach to scheduling is the use of network techniques such as Program Evaluation and Review Technique (PERT) and Critical Path Method (CPM), well known as the Arrow Diagram Method (ADM). PERT was developed by the US Navy in 1958. At about the same time that the Navy was developing PERT, DuPont, Inc. initiated CPM (Kerzner, 1998). Both techniques define the schedule plan in graphical form (a network diagram) with a critical path. Three basic symbols are used to construct the network diagram, illustrating (1) the activities (full-arrow); (2) dependence (dotted-arrow); and (3) event (circle), see Fig. 7.8.

Process technology and production flow-time determine the sequence of activities when constructing a schedule. Activities can be consecutive, overlapping, or parallel/simultaneous. A network chart with arrows is composed of those activities that require a definite time to be performed, also indicating a technological relationship between two activities, or the technological flow of interconnected activities. When constructing a network chart, the following rules apply:

- each activity should start and end with an event;
- if the end of one activity is a precondition for starting another, the final event of this activity should match the start of the next;
- only a single activity can exist between two events;
- there should be no loop;
- no activity is allowed to begin before its starting event;
- no event should take place until all the activities that lead up to it have been completed;
- all the events in a network chart should be numbered with each successive event allocated a higher number from the last.

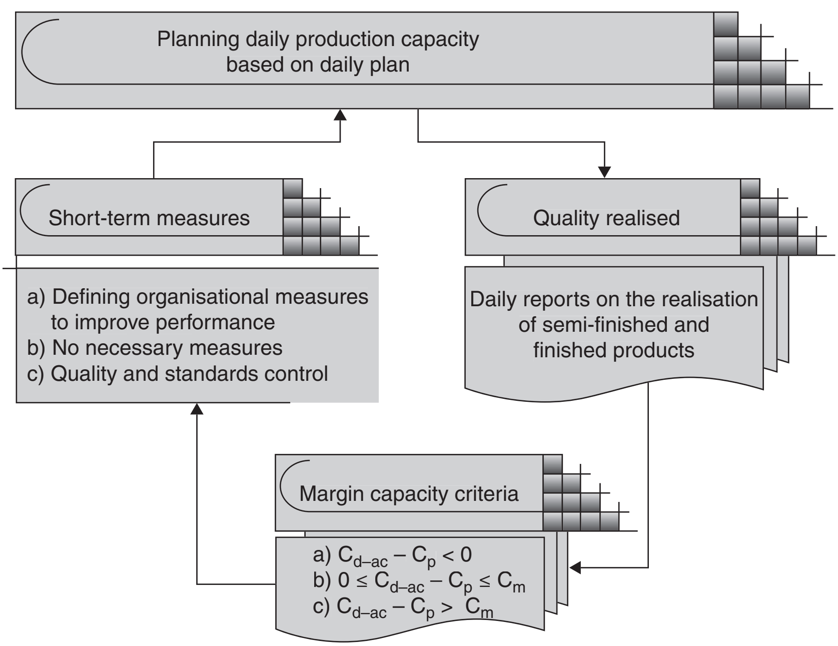


7.8 A schematic representation of a closed-network chart with arrows.

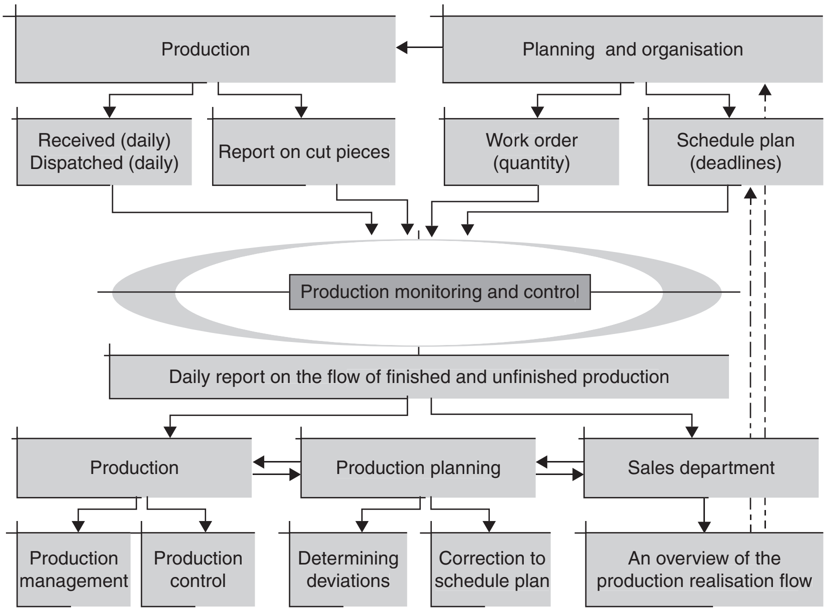
7.5 Production monitoring and control

Continuous monitoring and control of the number of semi-finished and finished products, and concurrent product quality monitoring, are important factors in any production process. This monitoring and control should be organised according to predetermined time intervals, so as to compare the planned state of production C_p with the actual quantity produced, that is, with the actual production capacity $C_{d\text{-}ac}$. The results from production monitoring and control are used to evaluate the success of a production process. Figure 7.9 shows a schematic representation for production monitoring and control, and necessary measures to take in cases of unacceptable deviation. The criterion for evaluating the success of a production process flow is the margin capacity C_m, which can be around 10% higher than planned capacity C_p (this percentage is defined in relation to the level of organisation and the production process flow-time).

Production monitoring and control reflects the success of a production process flow in relation to the planned flow. In addition, it offers data for direct production process management, as well as data to be used by the sales department, which can now check whether production realisation is adequate (from the point of view of the order). Sales can also check the deadlines for product delivery to buyers or customers, and suggest



7.9 Analysis of production monitoring.



7.10 A scheme for production monitoring and control within a production management process.

adjustments where necessary. Figure 7.10 offers a schematic representation of production monitoring and control, and information transfer. As well as recording the amount of semi-finished and finished products at a particular time, production monitoring and control is an important factor in reducing costs, namely through ensuring a high-quality, uninterrupted and controlled flow of material.

7.5.1 Data requirements for production monitoring and control

Production monitoring and control has become a demanding task. Production of high fashion clothing of widely varying design results in numerous work orders, each with a small number of almost unique articles of clothing. This type of work order is characterised by small series, decreasing flow-times, and a wide spectrum of colours, designs, fabrics and garment sizes. An increased number of work orders at minimal sizes makes recording and calculating the work more difficult. Rather than reducing staff involved with recording and similar paperwork, staff numbers grow, contrary to requirements for higher productivity. Operators in direct manufacturing waste more and more time on their personal recording of work done; efficient production suffers, leading to an unnecessary decline in productivity. It is therefore important to implement efficient monitoring and control, both regarding time spent recording by operators and efficient data storage.

Efficient production process planning asks for as much information as possible on the production process flow, so as to minimise production costs. This information should be obtained using an appropriate system of production monitoring and control. The following must be determined in order to acquire effective information:

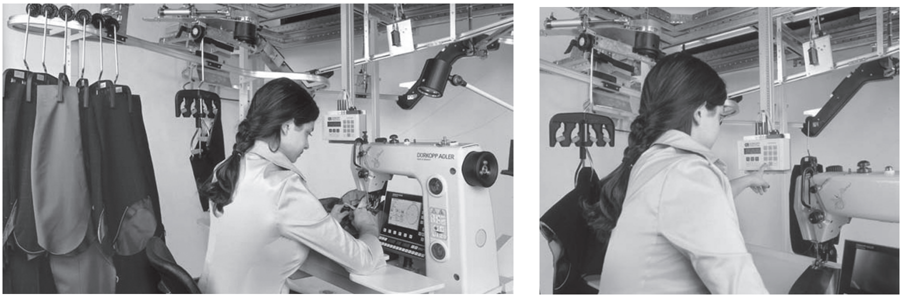
- points where data needs to be extracted, which could include all the input and output areas of individual processes;
- the data acquisition method, that is, using a keyboard, optical reader, magnet card or chip card;
- the amount of data to be taken and the sequence of acquisition (the amount of data is often limited by method);
- how and where data will be sent;
- the type of analyses and calculations to be performed, and the tabular and graphical representations necessary to plan and control production;
- security precautions and user access to data;
- the reliability of the data and data storage, including the system selected and manner of acquisition; software and hardware should be properly checked.

Existing systems of production monitoring and control can be divided into three groups by function (Geršak, 1991; Anon., 2003):

1. systems which collect data directly at workplaces,
2. systems used to monitor, control and manage production,
3. systems which collect data using technological processes.

Systems of production monitoring and control with data collected at the workplace are those in which the operator registers with a special card on arrival and then queries the monitor about the particular operation which he/she is going to perform. The data on the work done are collected using these cards. These are flexible systems, equipped with carts on which semi-finished products are attached on input. Each operator has his/her own magnetic card, which can be used only once in the system. At the beginning of the work the operator inserts his/her personal magnetic card into the computer slot at his/her workplace, and is then included in the system. This method is used to automatically record the operator during working hours, and interoperates with wage databases in the workplace. At the input point, that is, sewing preparation, the prepared garment parts are attached to a cart, whilst the data describing the parts are entered into the computer, including work order number, and model designation. After each operation, the operator confirms completion by depressing the relevant button. In this

(a) (b)



7.11 An example of data acquisition at a workplace (a and b) (Anon., 2003).

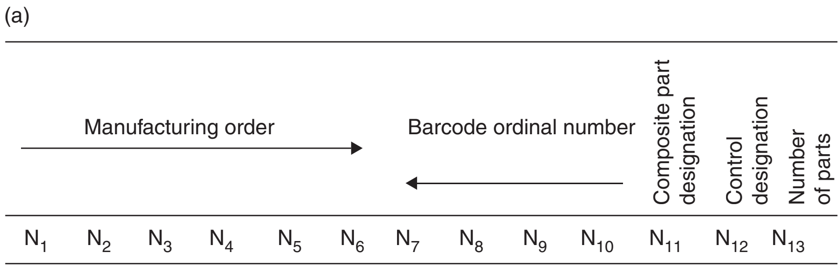
way the system acquires information on progress. Figure 7.11 gives an example of data acquisition at a workplace (Anon., 2003).

Systems of production monitoring and control which use technological processes are systems that enable the creation of machine-readable barcodes containing data for each product. The primary function of a barcode is information transfer for product identification, from its origin in production to the point where this information is needed, such as a storeroom or point of sale. A barcode accompanies the product throughout every stage of production. Optical readers are situated between individual processes or production stages. Information is available for each work piece, describing which stage of the production process is in progress at any particular moment. Such data collection offers increased efficiency, prevents mistakes during production, and lowers costs considerably. There are numerous ways of writing barcode data. In industrial practice two systems are used – GS1–13 (ex EAN 13) and GS1–128 (ex EAN 128), the latter being able to write numbers and letters, as well as to produce entries of various lengths for various end uses (GS1, 2012; Brown, 1997). Figure 7.12 shows an example of a structure with non-standard contents and symbol entry GS1–13 barcode used for production monitoring and control (Anon., 2011b; GS1, 2012).

7.5.2 Computer-aided production monitoring and control

Growing demands for the efficient use of information for planning, managing and controlling production processes have led to the need for production monitoring and control to be properly organised and computerised. Monitoring and calculation of in-plant operator productivity[1] is largely

[1] **Productivity** can be defined as the amount of output produced divided by the amount of input used. The greater the amount of output produced from a fixed quantity of inputs, the higher the productivity. *Operator productivity* is measured with the amount of work performed in a predetermined time unit.



(b) 7 2 5 1 9 1 0 0 0 7 1 2 9

7.12 Data structure and symbol entry of the GS1–13 barcode: (a) Entry data structure of the GS1–13 barcode; (b) Symbol GS1–13.

performed using computer databases. These databases include (Žižek, 1989; Rogale *et al.*, 1993, 1998) those:

- including operators, divided into working groups,
- including work orders,
- including technological operation plans,
- including daily working time structure for in-plant operators (norm-hours, presence at work, overhead hours content, etc.).

Computerised calculation of productivity is complex and includes a number of steps:

- recording production realisation or the work performed by in-plant operators,
- data entry into the system,
- data control and processing,
- production calculation,
- calculation analysis and listing,
- data transfer into the system for wages calculation.

Reports record production realisation. Daily reports on product dispatch from each working group are used to compose a list of semi-finished and finished products taken from each work order. These reports should include quantities in pieces, and the following information:

- working group designation,
- dispatch or delivery date,

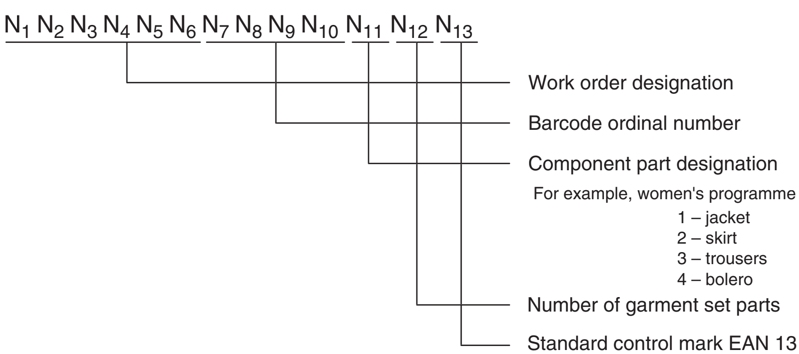
- number of operators within the working group or at work,
- work order designation,
- number of pieces entering the working group or dispatched from the working group.

Data from these reports are stored in the computer. Various computer-based methods exist for entering data and calculating productivity at all stages of clothing manufacture. Data input can be implemented in the conventional way, usually at the end of a shift, or automatically with data being entered later. Special recording cards with labels for barcodes are used, or the data are entered in an automated manner.

7.5.3 Production monitoring and control using barcodes

Databases from work orders represent a basis for production monitoring and control. As work orders differ by structure (they may be composed of multiple orders, and include various garment sizes and colour variants or patterns), their structure should be taken into account when selecting designators for identification purposes. Figure 7.13 shows an example of a work order structure in use (Gerenčer, 2009).

A special database for barcodes is created on the basis of the work order structure. Barcodes provide the sequence of a quantity of products by particular garment size or design. A barcode database contains a barcode key-basis in addition, Fig. 7.14 (Gerenčer, 2009), and the definition of a particular barcode flow throughout the production cycle. A barcode with non-standard content is often used for production monitoring and control, designed as an internal barcode with the following data structure:



In the case of monitoring and controlling a 4-part set, that is, a set consisting of four components (e.g., part 1 – jacket, part 2 – skirt, part 3 – trousers and part 4 – bolero), four barcodes will be entered,

(a)

MPN0112 ------------ Manufacturing order quantities ------------ Szl Mura

1/t/order 9 3 5046 Launched 12.4.11 Finished NO Signature X ze 423
Order NAR
Buyer 09148 Trendline, Germany Type E lohn Trendline
Order Manufacture 003 MURA

Product order	no. colour	zt	Type	Launched	Cut.	Accepted	O.K.	
84823 00147	06 01 17	5 4	001	290	1	1	1	0
84823 00147	06 02 17	1654	002	13	0	0	0	0
84823 00147	06 03 23	5 4	003	35	0	0	0	0
84823 00147	06 04 79	5 4	004	72	0	0	0	0
84823 00147	06 05 79	1654	005	13	0	0	0	0
	Total quantity —>			423	0	1	1	0

Parts >1> women's overcoat > > > >
------------------------------electronic signature ══> pf5, pf6 --

(b)

MPN0113 Order 9 3 5046 Product 84823 design 00147 figure 06 colour 01 423
Women's overcoat 199904121
Figure 06 colour 01 Women's overcoat
Design material A44
Colour 17 5 4

Size	34	36	38	40	42	44	46	48	50	52
Launched		5	41	54	57	61	49	21	1	1
Cut piece		1								
Accepted		1								

Size	54
Launched	
Cut piece	
Accepted	

Size	
Launched	
Cut piece	
Accepted	

In colour : cutting pieces 1 accepted 1
By order : cutting pieces 1 accepted 1 description
Out ==> clear, enter, pf3

7.13 An example of a launched work order structure: (a) Launched work order; (b) Launching open line (the first line from Fig. 7.13a).

differing in component-part designation. The barcode for the jacket will be $N_1N_2N_3N_4N_5N_6N_7N_8N_9N_{10}$14K, for the skirt $N_1N_2N_3N_4N_5N_6N_7N_8N_9N_{10}$24K, for the trousers $N_1N_2N_3N_4N_5N_6N_7N_8N_9N_{10}$34K, and for the bolero $N_1N_2N_3N_4N_5N_6N_7N_8N_9N_{10}$44K. Using barcodes which include set part-designations as their identification units, and which accompany the product throughout the individual phases of production, it is possible to establish where a product is at any time.

7.5.4 Production monitoring and control system

The work order should be entered into the system before collecting data from the report on accepting products from each working group. Each work

```
MPN0037 ---------  Order   9 3 5046   Review of article flow in production   ------------ ERC Mura

Order ------ > 9 3 5046      Set pieces :                                              Page :  1
------------------------------------------------------------------------------------------------
! product des   no. col   !  no. size   !1!cutting ! sew   ! press !  adj   ! compl !  Lj/Le!  g!o!- opo s!
! 84823 00147 06 01       !    1 36     !x! -----!-----!-----!-----!-----!-----!-!-! ***  0!
!                         !    2 36     !x! -----!-----!-----!-----!-----!-----!-!-! ***  0!
!                         !    3 36     !x! -----!-----!-----!-----!-----!-----!-!-! ***  0!
!                         !    4 36     !x! x----!x----!x----!x----!x----!-----!x!x! ***  0!
!                         !    5 36     !x! -----!-----!-----!-----!-----!-----!-!-! ***  0!
! 84823 00147 06 02       !    6 36     !x! -----!-----!-----!-----!-----!-----!-!-! ***  0!
!                         !    7 36     !x! -----!-----!-----!-----!-----!-----!-!-! ***  0!
! 84823 00147 06 03       !    8 36     !x! -----!-----!-----!-----!-----!-----!-!-! ***  0!
! 84823 00147 06 04       !    9 36     !x! -----!-----!-----!-----!-----!-----!-!-! ***  0!
!                         !   10 36     !x! -----!-----!-----!-----!-----!-----!-!-! ***  0!
!                         !   11 36     !x! -----!-----!-----!-----!-----!-----!-!-! ***  0!
! 84823 00147 06 05       !   12 36     !x! -----!-----!-----!-----!-----!-----!-!-! ***  0!
!                         !   13 36     !x! -----!-----!-----!-----!-----!-----!-!-! ***  0!
! 84823 00147 06 01       !   14 36     !x! -----!-----!-----!-----!-----!-----!-!-! ***  0!
!                         !   15 36     !x! -----!-----!-----!-----!-----!-----!-!-! ***  0!
!                         !   16 36     !x! -----!-----!-----!-----!-----!-----!-!-! ***  0!
------------------------------------------------------------------------------------------------
Commands: P/N forwards, P/P backwards;     P/1  first,    P/L  last
Review summary ==> last page                                   Browse command :        P/N
```

7.14 Barcode key-base and barcode flow throughout the production.

order should have a technological operation plan in order to calculate the necessary manufacturing time. The data on the number of cut pieces for a work order should also be entered. The product engineer should also input the following data:

- buyer's name and who the work order is intended for,
- acquisition or seasonal number,
- manufacturing date.

When the data from the report are entered, the computer system adds the following data from other programs:

- product or model name,
- launched (ordered) number of pieces for a particular work order,
- manufacturing time in the sewing room (from the operation plan),
- number of cut pieces.

Using data collected from these reports, the system calculates the available and necessary fund of working hours for each working group, as well as effective daily productivity (for accepted and dispatched quantities) and then stores the actual states of the semi-finished products by piece and minutes for each work order and each working group.

A number of tables are outputted:

(a) A monthly review of the accepted work for the sewing room, where the following data for each of the work orders are presented:

- acceptance date in the month,
- work order designation,
- product or model name,
- number of launched pieces,
- number of cut pieces,
- number of pieces accepted on a particular day,
- overall number of accepted pieces (cumulative),
- the states of semi-finished products,
- standard time,
- number of operator at work.

(b) A monthly review of dispatch from sewing room, the data being identical to the review of monthly acceptance to the sewing room, with the addition of data on:
- deadline for goods delivery to the buyer,
- write-offs (in pieces),
- productivity.

(c) A monthly production review by working group including the review of accepted and dispatched goods for each work order. Acceptance and dispatching are monitored for each work order on a particular day, as well as cumulative semi-finished products.

(d) The review of semi-finished products by working groups should be updated. This informs management when making business decisions, and group leaders who need to control manufacturing more efficiently. The following important data are obtained for each work order:
- article/product,
- buyer,
- launched number of pieces,
- cut-number of pieces,
- the state of semi-finished products,
- standard time for a single product/piece in the sewing room,
- planed deadline for the delivery of goods to the buyer,
- the date of the first acceptance into the sewing room,
- the date of the last dispatch from the sewing room,
- total number of pieces in the form of semi-finished articles.

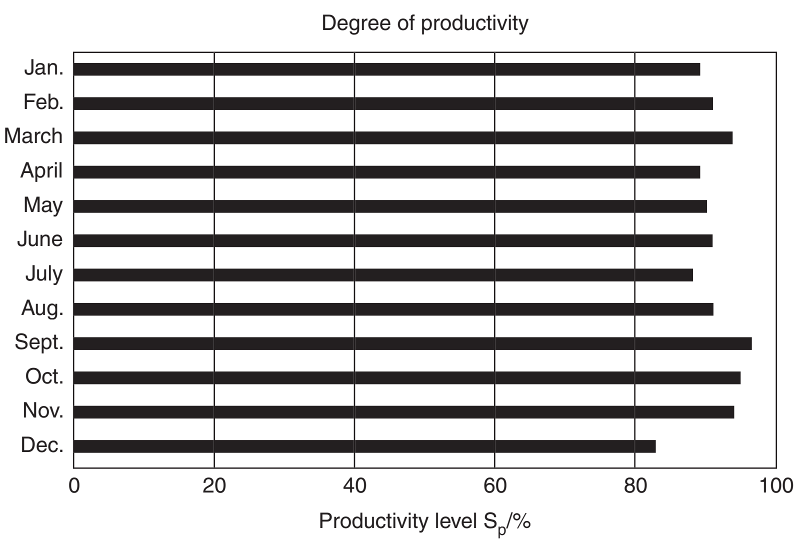
(e) A review of semi-finished products by buyer, the results obtained by monitoring and control showing semi-finished products in each working group. Launched, cut, accepted and dispatched pieces can be compared; production deadlines established; manufacturing time determined per single piece; and cumulative time for all pieces in the form of semi-finished articles arrived at. This table can also show average manufacturing time for semi-finished pieces, and the total time necessary to process them.

(f) The review of dispatched consignments; monitoring and control can follow the data for each individual consignment sent to a particular buyer following each work order:
- launched number of pieces,
- article type or model,
- finished product number,
- semi-finished product number in the sewing room,
- manufacturing time,
- deadline for delivery of goods to the buyer.

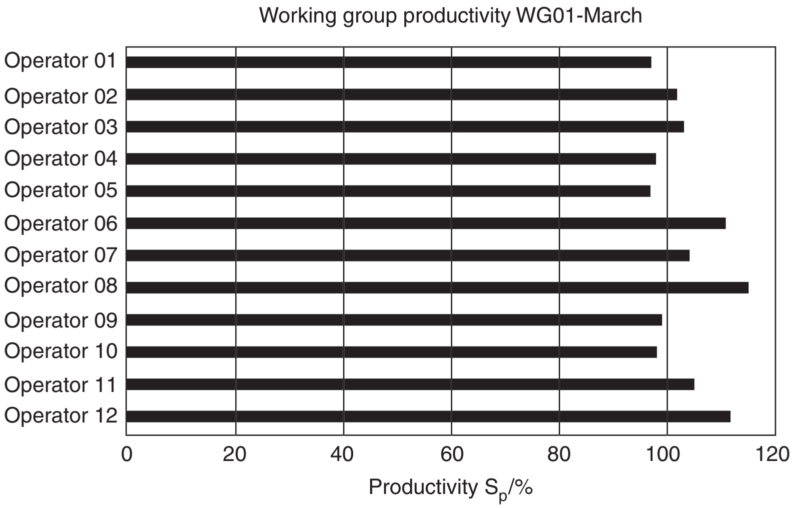
Data input should include an actual dispatch date for each individual work order. This enables a comparison to be made between planned and actual delivery rates.

(g) Sewing room realisation, as related to the actual fund of working hours, is essentially a table indicating the acceptance and dispatch of pieces for each individual working group, and for the whole of the sewing room, expressed in percentages.

The data in the databases for production realisation can also be used for certain calculations and analyses. Results can be used for a daily calculation of standards reached by individual operators; monthly norms, and; the degree of productivity. The degree of productivity over a period of months for a sewing room working group can be seen in Fig. 7.15. Important



7.15 An example of a sewing room working group's degree of productivity.



7.16 An example of a working group's increased productivity, as the result of production monitoring and control.

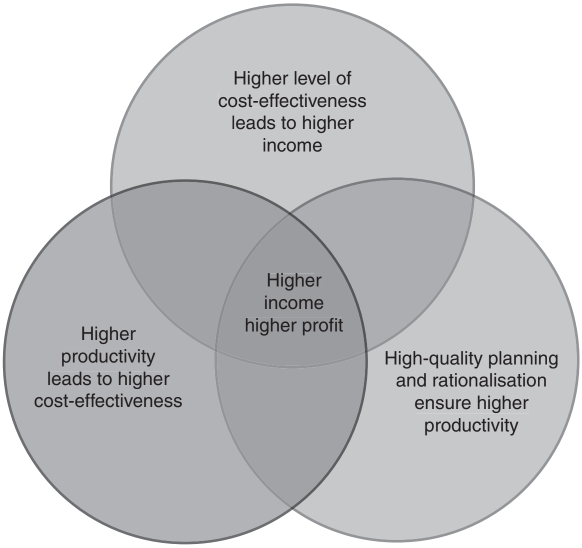
parameters obtained by production monitoring and control include, among others:

- daily calculation of work realisation for each operator,
- monthly calculation of work realisation for each operator,
- daily calculation for each working unit,
- monthly calculation for each working unit,
- daily calculation for each work order,
- final calculation of work realisation for each work order.

Production monitoring and control also reviews the situation during production and identifies deviations of the actual from the planned situation. An example of increased productivity in a working group as a result of production monitoring and control can be seen in Fig. 7.16. Documents from storage operations offer important feedback on production realisation, for material flow and operator productivity (i.e. the data on the work done used to calculate wages, as well the data to be used in post-calculations such as those informing future business decisions).

7.6 Costs in production planning and management

In order to gain advantage over the competition, rapid product development and high-quality, short flow-times are important. High-quality production planning contributes to this aim. Production planning includes clothing design



7.17 Joint effects of productivity, cost effectiveness, and profitability.

analysis and careful production planning and management, internal logistics and transport, and material management. Production planning and management are the key factors in success or failure within manufacturing. Cost effectiveness and profit should be the main principles in production monitoring and management. Every step should be taken in management towards the rational and optimal exploitation of the workforce and equipment. Figure 7.17 shows the impact of production planning and rationalisation on company productivity, cost effectiveness and income.

The following factors show the level to which this principle is realised within an enterprise:

a) Productivity is defined as the amount of output produced, divided by the amount of input used, the ratio between the result as a quantitative effect, and the costs necessary to obtain the targeted result:

$$P = \frac{Q_O}{Q_{CO}}. \qquad [7.24]$$

Inputs include labour and capital, while output is typically measured in revenues and other GDP (gross domestic product) components such as business inventories.

b) Cost effectiveness is defined as the ratio between the income or output, on the one hand, and inputs,[2] on the other, for example the ratio between sales and costs. It is expressed as follows (Plinke, 1997; Nebel, 2007):

$$E = \frac{O}{I}, \quad [7.25]$$

where:

Q_o output or quantitative effect,
Q_{co} quantitative spending or costs,
O output or the effects expressed through costs (e.g., number of products),
I input or costs.

Cost effectiveness is satisfactory if the ratio is:

$$E = \frac{O}{I} \geq 1. \quad [7.26]$$

b) Profitability is defined as the ratio between the profit over a particular time period (month, quarter, season or year), and the average capital investment, expressed as:

$$R = \frac{I_{co-s}}{K} \cdot 100, \quad [7.27]$$

where the profit is expressed as:

$$p = I_{co} - S. \quad [7.28]$$

Profit is reflected in reduced liability, increased assets, and/or increased equity for the owner. Profit furnishes resources for investing in future operations and its absence may evidently result in disaster for the firm.

Equation [7.27] can also assume the following form:

$$R = \left(\frac{I_{co} - S}{I_{co}} \cdot 100\right) \cdot \frac{I_{co}}{K} = \left(\frac{p}{I_{co}} \cdot 100\right) \cdot \frac{I_{co}}{K}, \quad [7.29]$$

[2] **Input** – data, incoming values, costs. Item external to a system (such as a process) that is transformed by the system (usually together with one or more other items) to become an output.

where:

R profitability,
I_{co} income,
S costs,
p profit or gain,
K capital used.

The expression [7.29] shows that profitability is composed of two segments, profitability of the income $R_{I_{co}}$, which indicates how much profit has been realised from the income obtained:

$$R_{I_{co}} = \frac{I_{co} - S}{I_{co}} \cdot 100, \qquad [7.30]$$

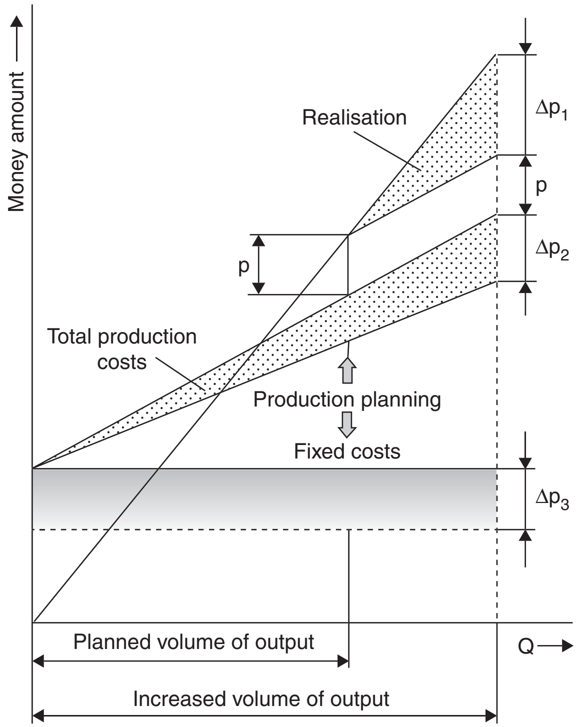
and the degree of capital turnover D_K:

$$D_K = \frac{I_{co}}{K}, \qquad [7.31]$$

which says how many times it is possible to turn over the capital within a predetermined time period.

Demand for clothing is relatively seasonal, with peaks during spring/summer and autumn/winter seasons, making for low capital turnover. Turnover is often only twice a year, which can in some cases be improved by the number of collections and successful marketing strategies. Additionally, high-quality production planning can have a significant positive impact on business. The impact of production planning on a company's success can be seen in Fig. 7.18 (Polajnar, 2006; Nebel, 2007). High-quality production planning contributes to success in three ways:

1. Through increased profit Δp_1, resulting from increased production volume whilst keeping fixed costs at the same level. This kind of production increase is most beneficial and is the result of all production planning, work study and process optimisation aimed at the optimal utilisation of available capacity in order to increase production volume.
2. Through increased profit Δp_2, resulting from reduced variable costs. Cost reduction can be achieved by proper planning, and introducing simpler and more efficient methods to ensure a high-quality and uninterrupted process (e.g., introducing adequate methods of work with associated work piece feeds (see Section 6.5)).
3. Through increased profit Δp_3, resulting from a reduction in fixed costs (interest on working and equity capital, fixed material costs, workers' overheads, etc.). This kind of cost reduction can be achieved by proper planning of long-term improvement, primarily in the areas of fabric



7.18 A graph depicting company business.

utilisation and flow, transport, storage and better utilisation of overheads and staff, which all influence fixed costs.

Apart from the conventional measures, other measures should also be defined in order to assess how business goals may be attained. These include:

- absolute measurement, which shows how much money the company has earned (pure profit),
- relative measurement, which is the ratio between input and profit (profitability of the investment),
- money-flow, which tells whether enough financial means comes into the company to cover all the costs.

These measures can be used to determine production efficiency. Broadly speaking, a company's performance can be evaluated through its efficiency as well as through the following practical measures:

- Production flow or production per time unit this is the rate at which the system earns money through sales (not through manufacture, as manufactured products in storage generate no money),

- Supplies all the financial means the system invests into the purchase of various things it plans to sell later,
- Operating costs all the money the system needs to change supplies into products for sale.

Apart from direct planning and production management, all reasonable measures should be taken to achieve maximum cost effectiveness. Accurate information on costs is key when making decisions.

7.6.1 Calculations

A calculation is an economic notion to denote a determination of costs, necessary to reach a price for a product or service. As V. Potočnik states, a calculation is a procedure used to determine purchase, sales and other prices, whilst it can also be a distribution of costs to those products or services that have caused particular costs (i.e. cost bearers) (Potočnik, 1999). Calculations are divided by various criteria, including contents and purpose. Calculations by contents are those:

- calculations pertaining to operating costs as a whole,
- cost calculations for individual cost bearers.

Calculations by purpose are those :

- preliminary calculations, known as planned calculations,
- simultaneous costing, known as intercalculations,
- subsequent calculations, known as accounting calculations.

Preliminary or planned calculation is carried out in the course of preparing a collection, when the evaluation and planned values for the following are known:

- material requirement,
- manufacturing time requirement,
- material prices,
- labour prices or time unit prices,
- degree of coverage.

Preliminary or planned calculation is used to determine retail price or to predict sales, manufacture and purchase, in terms of quantity and value. Input data are primarily material costs (determined by list of material) and planned manufacturing time.

Intercalculations are those prepared in order to check processes on-line, with the aim of reducing costs within a particular process, and improving business performance as a result. Intercalculations are made based on actual standards of fabric consumption, obtained from cutting-markers, and planned standard time, as determined by operational plans.

Subsequent or accounting calculations are made on completed production, and are based on the actual values of material consumption and on real manufacturing time.

The following principles apply when making basic calculations (Potočnik, 1999), and managing the business process always requires these forms of calculation:

- the principle of accuracy – calculation should accurately include all the costs incurred or to be incurred in manufacturing a product or in performing a process;
- the principle of cost differentiation – calculation should ensure that costs are objectively attributed to where they occur, and to cost bearers, by the types of costs;
- the principle of adaptability – calculation should be matched to the type of effect, the technological process in question, the type and manner of manufacture, and the conditions prevailing within the company;
- the principle of comparability – calculation should be shaped so as to be comparable with other calculations within the same company and elsewhere (preliminary calculations, intercalculations, and accounting calculations should also be comparable);
- the principle of rationality – calculation should be shaped so that the costs of its preparation are not higher than the merit of its preparation and usage.

When preparing a collection, we generally have at our disposal cost evaluations or planned cost categories. The result is a preliminary or planned calculation, which can be used by the sales department to determine retail price. When the work order is launched into production, we can see whether the costs of preparing a new collection have been properly evaluated. At this moment we do not deal with evaluations but with actual standards of fabric use (obtained from cutting-markers) and standard time (obtained from operational plans), as well as with the value of material according to the actual purchase price.

These real data are used to make a calculation, or intercalculation, used to determine production and sales over a period of time. By analysing the data obtained, we learn whether the previous calculation was correct, and whether plans were accurately drawn up. If this is not the case, the analysis tells us what measures should now be taken. When, due to some objective and/or subjective problems, predictions from the planned work orders do not come to fruition (e.g., lower fabric quality), the actual costs should be checked. Subsequent calculations, or accounting calculations, are made for each work order, with actual data being input from the requests or material return form, together with the total working hours of individual operators for a particular work order, obtained from production monitoring and control. This type of calculation shows precisely whether the production flow has been within planned tolerances, or whether deviations have occurred; if so, it offers the answers as to the where and why.

7.6.2 Determining costs

Costs are expenses, expressed in monetary units, spent on those goods or services necessary to realise production capacities. Costs are thus values for material procured, depreciation, write-offs, expenses for loans and credit, cost of unpaid debts, cost of work, and taxes. Costs can be divided in various ways:

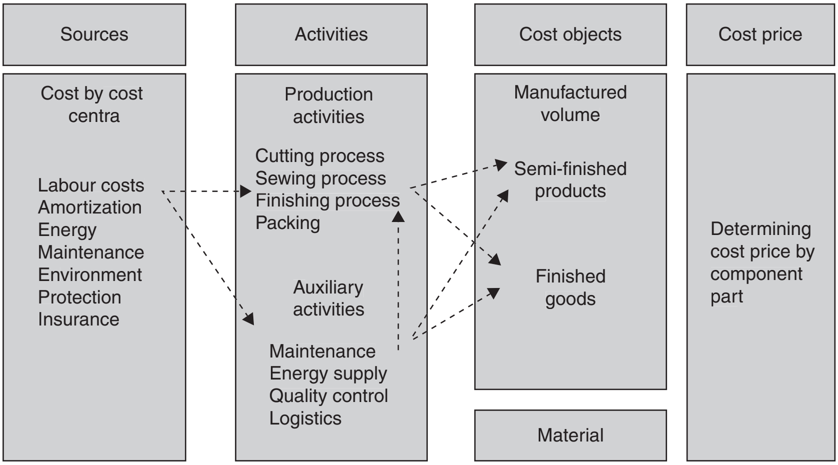
- by form (such as material, wages and salaries with benefits and taxes, financial costs, service costs, and development costs for new products);
- by origin (such as manufacturing costs, storage costs, overhead costs, and managing costs);
- by whether they are direct or indirect (direct costs associated with a particular product or service, and indirect costs associated with the business as a whole);
- by their relation to changes in business volume (fixed costs that do not change and variable costs that change with conditions).

Costs can be viewed as three different modules, Fig. 7.19 (Mihelič, 2003):

- origin, composed of costs organised by cost centres;
- activity, which is the module of costs;
- cost objects, which are the result of working activities and are generally products, but could be customers as well.

Activities are divided into two groups:

1. Productive activities are formed by individual production lines or working groups. Each productive activity is composed of two sub-activities:
   - the first includes depreciation costs, maintenance and insurance and are fixed costs (FC);
   - the second includes costs associated with direct productive work, energy, as well as the other costs that change and are variable costs (VC).
2. Auxiliary activities support productive activities. The most important are those pertaining to maintenance and energy supply. The costs of these activities are assigned to production activities, whilst other auxiliary activities (such as quality control, and logistics) are assigned to products.



7.19 Modular cost structure.

Separating activities into sub-activities enables FCs and VCs to be analysed, or production costs to be divided into those dependent upon the unit of the product, its series or collection. Material is the most important individual cost, often representing as much as 40% of product value. Material is followed by costs of direct work (time used to manufacture a product). Following material and direct work, depreciation is the next most important cost. Special attention should be also paid to maintenance costs in production.

7.6.3 Calculation types

By type, calculations may be appropriation calculations or calculations with allowances. By complexity of form, they may be (Plinke, 1997): cost calculations regarding direct costs (also known as direct costing), or process cost calculations, which are appropriation calculations by nature, dealing with costs by their processes or parts.

Calculations differ according to the methods of collecting and accepting costs, as well as by the type of production they involve, with some production types requiring specific calculations.

7.6.4 Calculation elements

With cost structure shifting towards higher general costs (meaning the costs of management, and sales and purchase overhead costs as general production costs) it is often difficult to assign general costs objectively to particular products. This leads to an improperly defined and imprecise cost price, which in turn often incurs disadvantageous business decisions. Calculation elements that include the full cost price, or price based on costs, are:

(a) direct costs:
- costs of the material used during manufacture,
- depreciation costs,
- manufacturing costs (primarily costs of wages and salaries),
- other direct costs of manufacture;

(b) indirect costs:
- general manufacturing costs,
- management, sales, and purchase overhead costs.

Full cost price C_{fc} is defined as the sum of the overall costs plus the profit per unit product, reduced by a loss per unit product, and is calculated as follows:

$$C_{fc} = S_f + p - S_{loss}, \qquad [7.32]$$

where:

C_{fc} full cost price,
S_f full costs,
p profit per unit,
S_{loss} loss per unit.

Selling price C_s can be expressed as:

$$C_s \neq C_c, \qquad [7.33]$$

$$C_s > C_c, \qquad [7.34]$$

$$C_s < C_c, \qquad [7.35]$$

where:

C_s selling price per unit,
C_c cost price as the sum of all the costs.

This means that profit can be realised per product unit if the selling price is higher than the cost price, and with loss below it. Individual calculation methods comprehend the above elements differently. Calculation accuracy depends not only on the selected elements, but also on how costs are recorded.

7.6.5 Appropriation calculation

The appropriation calculation is the most frequently implemented calculation method. It is adequate for the production of products which are identical or similar to one another. Appropriation calculations can be simple or complex. A complex appropriation calculation is made so as to enable the monitoring of costs by:

- production process phases,
- places where effects occur,
- price structure elements.

Cost price defined as costs per unit product can be calculated as follows:

$$C_c = \frac{S_f}{V_P}, \qquad [7.36]$$

where:

S_f full costs,
V_P production volume.

This method has the advantage of offering cost reviews by production phase, by processes, or by cost centres, meaning that costs are more properly monitored and controlled, and responsibility for them can be attributed more precisely.

7.6.6 Direct costing

Direct costing is a calculation based on the notion that direct costs can be calculated more precisely for each product. Direct costing also offers the possibility of calculating indirect costs for the whole working unit, department, or enterprise. This method enables the calculation of all direct costs per product item, as well as all indirect costs taken as FCs for the whole unit, rendering it superior to more conventional methods. Knowing the retail price for each product, it is possible to calculate the coverage factor, which is how much the unit product contributes as a unit to covering FCs within the whole of planned production. Coverage part P_{co}, expressed as the difference between selling price and direct costs, can be calculated as follows:

$$P_{co} = C_s - \mathrm{VC}, \qquad [7.37]$$

whilst the coverage for the whole production is calculated as:

$$P_{coP} = (C_s - \mathrm{VC}) \cdot V_p, \qquad [7.38]$$

where:

- P_{co} part or contribution to covering the costs per unit product,
- P_{cop} part or contribution to covering the costs of overall production,
- C_s selling price per unit,
- VC direct costs,
- V_P production volume.

Part or contribution to covering costs can also be expressed as being related to selling price as a percentage, through degree of coverage:

$$S_{co} = \frac{C_s - \mathrm{VC}}{C_s} \cdot 100, \qquad [7.39]$$

where S_{co} represents degree of coverage or degree of contribution to covering costs.

Data obtained in this way can be used for determining the volume of output at which the threshold of profitability R_{pr} should be reached:

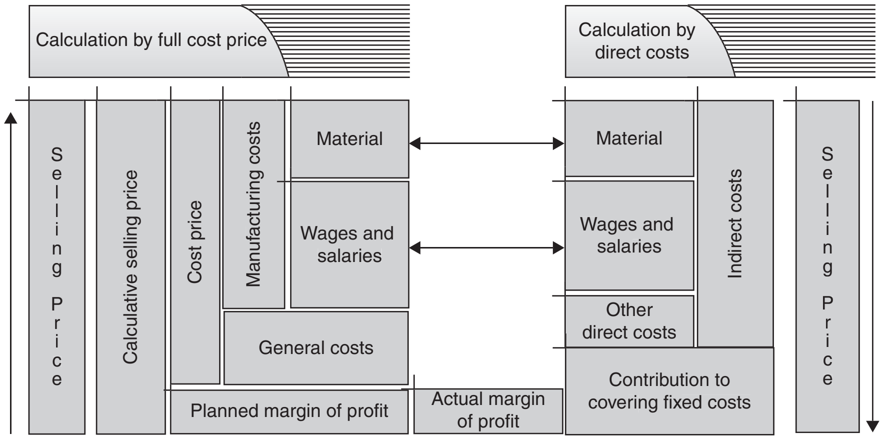
$$R_{pr} = \frac{\mathrm{FC}}{C_s - \mathrm{VC}} \cdot 100, \qquad [7.40]$$

where:

- R_{pr} profitability threshold, in pieces,
- C_s selling price per unit,
- VC direct costs,
- FC permanent or fixed costs.

Figure 7.20 shows a comparison of calculations made on the basis of full cost price, and by using the direct cost method.

Calculations provide a basis for company decision making. They are essentially accounting reports, offering accounting information, and information on financial means, on the levels of particular costs, on cost price, and on selling price, as well as information on business performance and results. In order to plan for success based on calculations, a company must define selling-prices, and perform relevant analyses of costs and business performance. The clothing industry is work-intensive, which means high flexibility (quick adaptation to customers' requirements and market demands). Developing new values and a high level of capacity utilisation are vital in order to achieve success. We should stress that these factors have their impact on cost levels. The central goal of each enterprise is to maximise profit. It is thus necessary for the management to be able to assess effects on costs and so define the part each individual product plays in realising profit.



7.20 Comparison of calculations made on the basis of full cost price and by using the method of direct costs.

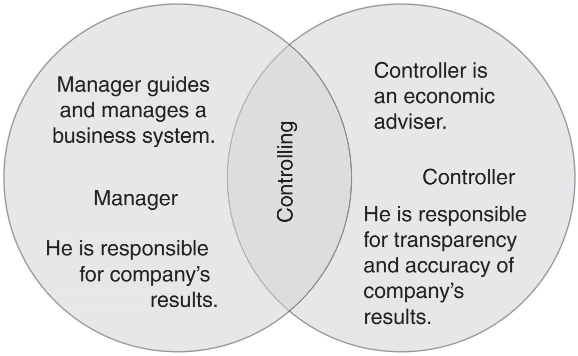
In every case, the goal should be to reach the highest possible profit, keeping all relevant factors in mind, whilst at the same time monitoring costs and income.

7.7 Controlling production planning and management

According to Brech, 'controlling is a systematic exercise of checking actual performance against the standards or plans with a view to ensure adequate progress and also recording such experience as is gained as a contribution to possible future needs' (Aquinas, 2007). Koontz and Weihrich (2008) define three basic steps for controlling:

(a) establishing benchmarks or standards,
(b) comparing actual performance against them, and
(c) taking corrective action, if required.

Controlling possesses the elements of strategy, operative management and control. It involves computer-aided data flow when planning, adjusting and controlling (Kaligaro, 2003). Controlling production planning and management means control over achieving planned goals, and includes information preparation, evaluation and shaping. Controlling does not denote orders issued by a controller, but is rather a management function of monitoring, Fig. 7.21. Controlling is performed by controllers and managers, meaning it includes the notion of *Management by Objectives*.



7.21 Control roles in monitoring.

Controlling is often characterised as a business philosophy (Kaligaro, 2003). It is a set of activities to shape the information needed to inform business decisions at various levels; it is involved in all the company business functions; and its success and performance are greatly dependent on all those persons involved in the process of information shaping and usage. F. Koletnik in this context says: 'Controlling is a business philosophy, a special manner of managing and (accounting) information activity, aimed at decision making. It is the engine and the steering wheel of the company and its management; it requires a purposeful and decentralised organisation, developed entrepreneurial culture, enterprise planning, and economic monitoring' (Koletnik, 1998).

In terms of function, controlling can be (Deyhle and Eiselmayer, 2007; Weber and Schäffer, 2008):

1. operative controlling, dealing with short terms, and organised so as to follow development strategy including four main areas:
   (a) planning (reaching predicted processes and conditions),
   (b) information collecting (determining working processes and conditions),
   (c) analysis/control (determining deviations),
   (d) managing (introducing measures);
2. strategic controlling which supports strategic enterprise management, involving information preparation needed for appropriate strategic decision making.

Controlling is thus a function and subsystem of company management. It improves productivity and enhances a company's ability to adapt to change, both internal and external. Management and controlling have the same goal: *to use existing potential effectively and create new potential for success*. However, their means differ. The basic instruments and subsystems of management are defining goals, planning, control, information flow, organising, and managing. Controlling is composed of coordinating and integrating these subsystems.

7.8 Conclusions

In the previous two chapters we have described the planning of clothing design, pattern making, cutting, and planning clothing manufacturing. In this chapter we have focused on production management as one of the critical phases of production, essential for all activity at every level of an organisation. Production management, which involves the planning, scheduling, monitoring and controlling of the whole production process, is key to efficiency as indicated by the ratio of output to input. This is especially important for clothing manufacture within the fashion industry, which is labour-intensive and characterised by an extremely large diversity of unique models. Each model or work order is produced only once, in a small series and very short flow-time, which requires an extremely flexible and harmonised management.

The key to optimisation lies in the ability of management to harmonise all available resources to maximise flexibility and productivity and ensure effective planning, scheduling and production monitoring. As has been shown, production management comprehends all those activities necessary to realise an order, and is based on the results of adequate planning concerning capacities planning, scheduling, and production monitoring and control. With the view that the clothing industry will be with us long into the future, clothing companies must adapt the way they manage production. Strong lines of production, a systematic information system, communication and cooperation will all be needed for successful and effective clothing production management in the coming years and decades.

7.9 References

Anon. (2002), *Big Dictionary of Foreign words* (in Slovenian), editor: M. Tavzes *et al.*, 1st edition, Ljubljana, Cankarjeva založba.

Anon. (2003), *Intelligentes Materialtransportsystem*, DATATRON 772 – Flexibles Material-transport-und Fertigungssteuersystem, Bielefeld, Dürkopp Fördertechnik GmbH, Dürkopp Adler AG.

Anon. (2011a), *REFA-Lexikon, Industrial Engineering und Arbeitsorganisation*. 3rd edition, Darmstadt, Auflage Darmstadt, Hrsg. vom REFA Bundesverband e.V.

Anon. (2011b), *User manual, GS1 Global business language* (in Slovenian), 12th edition, Ljubljana, GS1 Slovenia.

Anon. (2012), BusinessDirectory.com: Term of the Day. WebFinance Inc., the operators of www.investorwords.com, www.investorguide.com, and www.businessdictionary.com.

Aquinas, P. G. (2007), *Principles of Management and Organisational Behaviour*, New Delhi, School of Distance Education, Bharathiar University Coimbatore, Excel books private limited, 147–161.

Brown, S. A. (1997), *Revolution at the Checkout* Counter, *The Explosion of the Bar Code*, London, Harvard University Press.

Chase, R. B., Jacobs, F. R. and Aquilano, N. J. (2005), *Operations Management for Competitive Advantage',* 11th Edition, McGraw-Hill/Irwin.

Collins, P. and Glendinning, S. (2004), 'Production planning in the clothing industry: Failing to plan is planning to fail', *Control*, **1**, 16–20.

Deyhle, A. and Eiselmayer, K. (2007), *Controller and Controlling*, München, Verlag – Controller Akademie.

Eversheim, W. (1989), *Organisation in der Produktionstechnik, Arbeitsvorbereitung*, Band 3, Düsseldorf, VDI Verlag GmbH.

Gerenčer, M. (2009), 'Production monitoring using barcode in Mura d.d.' (in Slovenian), Murska Sobota, Mura d. d.

Geršak, J. (1991), 'Logistics – new development in the area of contemporary transport technique' (in Slovenian) – IMB'91, *Tekstilec*, **33** (7–8), 289–292.

Geršak, J. and Pevec, B. (1993), 'Garment industry development strategy – prerequisites for a successful and high-quality development of Slovenian garment manufacturing companies' (in Slovenian), *Tekstilec*, **36** (2), 49–55.

GS1 (2012), *GS1 System of Standards*, *The Value and Benefits of the GS1 System of Standards*, Available from: http://www.gs1.org/productssolutions/barcodes/technical/genspecs/index.html [Accessed 10 May 2012].

Horváth, P. (2011), *Controlling*, Vahlens Handbücher der Wirtschafts- und Sozialwissenschaften, 12., vollständig überarbeitete Auflage, München, Verlag Franz Vahlen München.

Kaligaro, J. (2003), 'Contemporary controlling as a support of successful company management' (in Slovenian), *Proceedings of 28th Conference on Enterprise Planning and Management*, Maribor, Society of economists Maribor, 163–171.

Kerzner, H. (1998), *Project Management, A Systems Approach to Planning, Scheduling, and Controlling*, Sixth edition, New York, John Wiley & Sons, Inc.

Koletnik, F. (1998), *Controlling and Management* (in Slovenian), Integral module Strategic management, Maribor, University of Maribor, Faculty of economy and business, MBA Postgraduate school of management.

Koontz, H. and Weihrich, H. (2008), *Essentials of Management*, Seventh edition, New Delhi, Tata McGraw-Hill Publishing Company Limited.

Mihelič, G. (2003), 'Successful management and contemporary controlling' (in Slovenian), *Proceedings of 28th Conference on Enterprise Planning and Management*, Maribor, Society of economists Maribor, 32–45.

Morris, P.W.G. (1997), *The Management of Projects*, London, Thomas Telford Services Ltd.

Nebel, T. (2007), *Produktionswirtschaft*, München, Oldenburg Wissenschaftverlag GmbH.

Plinke, W. (1997), *Industrielle Kostenrechnung*, Eine Einführung, 4. erweiterte Auflage, Berlin Heidelberg, Springer-Verlag.

Polajnar, A. (2006), *Workstudy* (in Slovenian), Second edition, Maribor: University of Maribor, Faculty of Mechanical Engineering.

Potočnik, V. (1999), *Calculations and DDV for Entrepreneurs, Craftsmen, and Retailers* (in Slovenian), Ljubljana, Gospodarski vestnik.

Rogale, D., Hudec, K., Ujevic, D. and Hudec, G. (1993), 'New approach to technological documents production in garment industry technological preparation' (in Croatian), *Tekstil*, **42** (12), 655–657.

Rogale, D., Ujević, D. and Rasinec, N. (1998), 'Computer-aided calculation of efficiency and production monitoring in garment industry' (in Slovenian), *Book of Proceedings, Clothing Engineering '98*, Maribor, University of Maribor, 58–66.

Rogale, D., Ujević, D., Firšt Rogale, S. and Hrastinski, M. (2011), *Garment Manufacturing Processes* (in Croatian), Zagreb, University of Zagreb, Faculty of Textile Technology.

Weber, J. and Schäffer, U. (2008), *Einführung in das Controlling*. 11. Auflage, Stuttgart, Schäffer-Poeschel.

Žižek, F. (1989), 'The role of computer-assisted processes in the company of Mura' (in Slovenian), *Book of Proceedings*, Maribor, University of Maribor, Faculty of Mechanical Engineering, 55–62.

8
Quality requirements for clothing materials

DOI: 10.1533/9780857097835.250

Abstract: This chapter reviews the importance of quality in textile materials and details some of the key requirements desired by consumers. The chapter then discusses the physical characteristics of fabrics, such as material construction, mass, finished width, design and other characteristics. The following sections deal with the specific performance characteristics of fabrics, such as: colour fastness, breaking strength, seam slippage, resistance to abrasion and pilling, and dimensional stability. The importance of care labelling for clothing and the Eco-Tex 100 standard are discussed. The chapter concludes by considering the impact of material testing on quality assurance.

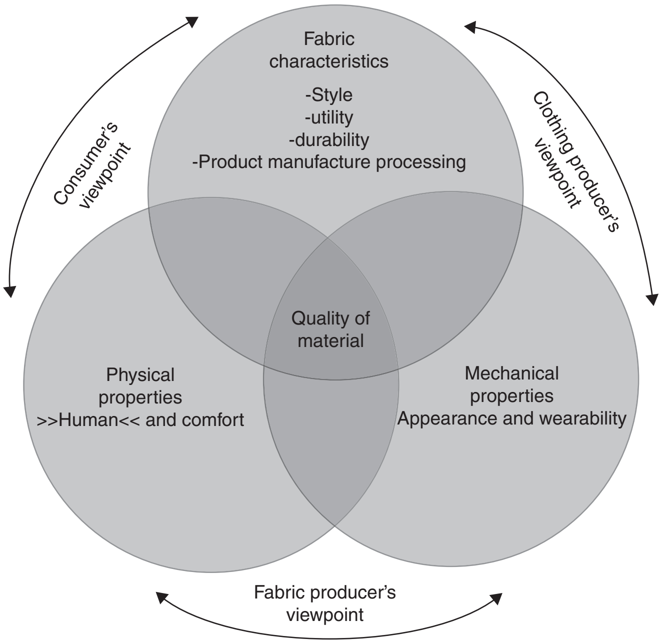
Key words: textile material, testing, quality, definition, minimum quality criteria, physical characteristics, performance characteristics, visible faults, care labelling, Eco-tex 100.

8.1 Introduction

Material quality plays a very important role in the clothing industry, because it is ultimately reflected in the quality of the final manufactured garments. The quality of textile materials can be viewed from three perspectives (see Fig. 8.1):

1. the consumer;
2. the fabric producer;
3. the clothing producer.

The consumer's interest lies, above all, in the appearance and wearability of the fabric, that is, in its durability, utility, comfort and style. A clothing manufacturer will be interested in both the consumers' requirements and in the manufacture and processing characteristics of the fabrics. Fabric producers must take into consideration the clothing manufacturers' processing requirements. With these different priorities affecting the requirements for the treatment of textile materials, clearly defined minimum quality criteria for textile materials are essential.



8.1 Key aspects in evaluating the performances of textile materials.

In order to be effectively used for clothing, textile materials must possess the ability to form a three-dimensional shape from their original two-dimensional shape, so that they can fit comfortably over the human body. This provides a graceful appearance to the fabrics that distinguishes them from other sheet materials. Textile materials possess exceptional characteristics, which, when incorporated into clothing, mean that they adapt to human body movements, allowing them to meet the wearer's physiological and psychological requirements, whilst maintaining an attractive 3D shape.

In view of the specific behaviour of textile materials and the growing quality requirements in planning clothing manufacture, the testing of materials has gained in importance. Knowing and understanding the quality criteria for textile materials and their behaviour during the manufacturing process has become a starting point for the planning of clothing, quality control, product development, process and product optimisation, as well as for computer-aided design, construction, and the numerical-modelling and simulation of clothing and other products for technical applications.

Testing materials for clothing, to ensure that they meet the technical and technological requirements imposed on them, involves mechanical, physical and chemical tests on both basic and auxiliary materials including accessories. It also requires defining minimum quality criteria based on quality-control requirements. These criteria impact on planning when determining processing parameters, and are designed to ensure the stability of the manufacturing process and the required quality level.

It is not the purpose of this chapter to cover individual test methods. The focus of the chapter is on quality requirements for clothing fabrics. If the reader wishes to know more about the kind of tests that can help measure different quality criteria, she or he is referred to the relevant international standards discussed in this chapter, as well as to other books which focus specifically on this topic, such as Hu (2008), particularly:

- Chapter 3 on fabric composition
- Chapter 4 on physical properties (fabric weight, thickness and strength)
- Chapter 6 on appearance testing (pilling, wrinkling, seam pucker and dimensional stability)
- Chapter 9 on colour fastness testing

Other books include: Houck (2009) on identifying fibre types; Fan (2005) on chemical tests in such areas as fibre identification, fabric finishes and dyes; and Saville (1999) on physical tests of fibre and yarn properties such as density, strength, dimensional stability, handle and colour fastness.

8.2 Quality requirements for textile materials for clothing

Quality in textile materials can be defined as conformance to requirements which are directly or indirectly set by the consumer. The key points regarding quality to note from the previous section are:

- the contribution of materials to manufacturing costs
- the link between the quality of the material and the quality of the finished product
- the need for continuity regarding product quality
- the means of improving communication within the consumer – clothing producer – fabric producer chain.

This last point could be achieved by the creation of clear and relevant recommendations concerning any characteristics and faults present in those fabrics to be used for clothing. This would then form a basis for the adoption of fabric specifications. The details of the fabric specifications would have to be dependent on local needs and the desired quality level of the final product.

The characteristics of a material's quality may be identified from the following basic categories of information:

(a) physical characteristics
(b) performance characteristics
(c) visible faults.

A detailed presentation of a material's characteristics should use the *Recommendations concerning characteristics and faults in fabrics to be used for clothing*[1] (DTB, 2006) as a starting point. These recommendations were prepared by the Technical Clothing Group of the European Federation of Euratex, and have been managed by GermanFashion since 2006. Their aim is to standardise practise between fabric suppliers and clothing manufacturers with regard to the ways in which they define and assess characteristics and faults in fabrics for use as clothing.

Differentiating products by quality is particularly important. Testing can be performed to improve product quality and to ensure compliance to international, regional or retailer-specific standards. The following sections provide a comprehensive review of those tests available for fabrics. Methods for selecting samples for testing are described in the individual standards discussed in this chapter. Further information can be also found in Chapter 2 on sampling and statistical analysis in Hu (2008). The broader role of testing within an overall quality management system is discussed in Chuter (2002).

8.3 Physical characteristics: types, methods of measurement and tolerances

The physical characteristics of a material detail its physical state, such as its construction, finishing treatment, mass, finished width, and other characteristics that are detectable by an experienced person with or without the aid of instruments. Irregularities in the physical characteristics of the material, excluding any predefined acceptable tolerances, are considered as '*faults*', on the condition that the irregularity is: (a) evident in the fabric as delivered, and (b) detrimental to the final clothing (DTB, 2006).

[1] **Recommendations** are based on the adopted criteria of the European Clothing Federation A.E.I.H. (Association Européenne des Industries de l'Habillement) of 1983 (Bona, 1994; DTB, 2006).

8.3.1 Mass per unit area

The mass per unit area is defined under the standards EN 12127:1977 and ISO 3801:1977 as the mass in grams per square metre of the sample, which will have been conditioned in the standard atmosphere for testing. Any differences in mass per square metre, up to a tolerance level of ±5% (DTB, 2006), when compared with the specifications in the contract, are considered to be faults. The material is tested for mass per unit area by taking the mass per square metre of the material as the total weight of the piece, divided by the exact length and the actual width including selvedge. In cases of dispute, the cloth is tested in accordance with the EN 12127:1977 or ISO 3801:1977 standards.

8.3.2 Number of threads per unit length

The number of threads per unit length is defined under standards EN 1049–2:1993 and ISO 7211–2:1984 as the number of threads per centimetre of the specimen that have been conditioned in the standard atmosphere for testing. The mean of the individual number for each direction is shown, for the warp threads, as ends per centimetre and, for the weft threads, as picks per centimetre. The fabric is considered to be faulty when the number of the ends and/or picks per centimetre of the warp yarn and/or weft yarn of the fabric delivered do not comply with the specification set out in the contract or with those of the standard specimen. The tolerance level for faults is 6% for carded fabrics, and 4% for all other fabrics (DTB, 2006). Standards EN 1049–2:1993 and ISO 7211–2:1984 have specified three methods (methods A, B, and C) for the determination of the number of threads per centimetre in woven fabrics. Any of the three methods may be used, and the choice usually depends on the type of fabric. In cases of dispute, however, method A is recommended.

The principles of these methods are:

Method A: a section of fabric is selected as follows:

- 10 cm for fabric with less than 10 threads per centimetre
- 5 cm for fabric with 10–25 threads per centimetre
- 3 cm for fabric with 25–40 threads per centimetre
- 2 cm for fabric with more than 40 threads per centimetre

The section is dissected and the number of threads is counted. Threads are typically 1–2 cm in length.

Method B: the number of threads visible within the aperture of a specified counting glass is determined.

Method C: the number of threads per centimetre is determined with a traversing thread counter.

8.3.3 Width

There are two definitions of fabric width: the overall width, and the usable width. The overall width is defined under standard ISO 3932:1976 as the distance, at right angles to the length of the fabric, between the outermost warp threads in the piece. Under the same standard, usable width is defined as the distance, at right angles to the length of the fabric, between the outermost warp threads of the body of the fabric. In accordance with EN 1773:1996 the usable[2] width of a piece is also defined as the width of the fabric excluding any selvedge materials, marks, pinholes or other non-homogeneous areas of the fabric. Faults in the fabric occur when the usable width of the delivered piece is less than that specified in the contract. No tolerance is allowed below the usable stipulated width in the contract. The maximum width must not exceed the usable stipulated width +4 cm (DTB, 2006).

There are several methods of testing the width of the fabric: In cases where the cloth has selvedge, testing is carried out by measuring the smallest distance between the two selvedges (the latter not being included in the measurement); in cloths without selvedge, the smallest distance between the two edges of the cloth is measured and 1 cm is deducted from each side; cloths with stenter-pin holes or marks are measured at the minimum width between the holes or marks on the cloth without tension. Where there is dispute, measurements are made according to ISO standard 3932:1976.

8.3.4 Length of the piece and length of an order

Length of the piece

The length of the piece is defined under ISO standard 3933:1976 as the distance between the outermost complete weft threads in a piece, excluding the weft threads of any different materials at the end(s) of the piece. In accordance with EN 1773:1996, however, the length of the piece is the distance between the beginning and the end of the sample in the lengthwise or machine direction. The material is considered to be faulty if (a) the delivered length (including faults) is different from the length of the piece as contracted, and/or (b) the length has been defined as the distance between the markers at the head and tail ends of the piece. On the length of

[2] The usable width may be defined differently for some end uses or specifications, as agreed between the interested parties.

each delivered piece the following tolerances are allowed, compared to the length specified in the contract (DTB, 2006):

- ±1% for woven fabrics
- ±2% for woven fabrics with elastane
- ±2% for knitted fabrics
- ±3% for knitted fabrics with elasthan.

The length of the piece is tested with a routine check, carried out using a calibrated measuring machine with a tolerance of ±1%. Where there is dispute, measurements are made according to the ISO standard 3933:1976.

Length of an order

The length of an order is defined as faulty when the length delivered[3] (in a particular type and colour) is longer or shorter than the ordered length. Faults are tolerated up to 2000 m: ±5%, for silk up to 1000 m: ±5% and from 2000 m: ±2%, for silk from 1000 m: ±2% (DTB, 2006). Testing is carried out by measuring the length of each piece forming part of the order and adding them up for the resulting measurement (DTB, 2006).

8.3.5 Weave

The weave of the material is considered to contain faults when a different weave from that of the typical sample or that specified in the contract is used. Testing is carried out according to ISO 7211–1:1984. The weave repeat shown on the design paper is adopted as the means for showing the weave of fabric and provision is made in the repeat for showing the disposition of different weaves. No differences are tolerated in the weave.

8.3.6 Composition

The composition of a material is considered to contain faults when the nature of the fibres of the fabric and/or their proportions, where there is a mixture, differ from the conditions stipulated in the contract. The tolerance for faults varies by country, but for countries in the European Union, testers can refer to EU Directives and/or the national legislation in force for countries outside the EU. The methods of testing the composition of a material also vary according to country. In countries in the European Union, the following directives can be used:

[3] **'Length delivered'** means gross length, including any possible faults.

- Directive 96/73/EC
- Directive 96/74/EC
- Commission Directive 97/37/EC and
- Commission Directive 2004/34/EC

Outside the European Union, unless there are special regulations regarding composition testing, ISO standards ISO 5089:1977, ISO 1833:1977 and ISO 5088:1976 can be followed.

8.3.7 Design

Faults in the design of a fabric are defined by a difference in design in relation to the sample, either due to shade variations in ground or effect yarns, or because the design dimensions differ from those specified in the contract. In the case of designs with a definite repeat (e.g. checks or stripes), the only disparities in design would be differences occurring between the delivered piece and the reference sample. Faults in the design of materials are tolerated to the following levels:

- Fabrics with visible weft: ±1.5%
- Uni–coloured fabrics: ±2.0%
- Double jersey: ±3.0%, and single jersey: ±4.0% (DTB, 2006).

Testing for design flaws is carried out by measuring the length of the fabric taken up by at least ten repeats of the design. In cases where the design is repeated within less than 10 cm, a measurement of at least 1 m is taken. The measurement should be taken in an area of the cloth free from strings (DTB, 2006). The measurements obtained are compared with those stipulated in the contract or, where there is no such stipulation, with those from the reference sample.

8.3.8 Irregularity of checks along the piece

Where the sizes of the checks on a fabric are not identical right through the piece, this is considered to be a fault. These are tolerated to the following levels:

- Fabrics with visible weft: ±1.5%
- Uni–coloured fabrics: ±2.0%
- Double jersey: ±3.0%, and single jersey: ±4.0% (DTB, 2006).

The regularity of the checks is tested with the cloth laid without tension on a flat, smooth surface. The warp is measured in several places along the length occupied by a given number of checks (at least five), the total length to be measured never being less than 70 cm (DTB, 2006).

8.4 Performance characteristics: types, methods of measurement and minimum quality standards

Performance characteristics comprise all the important functional characteristics of fabrics requiring specification and which can be measured with the aid of suitable equipment. The most significant areas are: dimensional stability; colour fastness to light; washing and dry-cleaning; breaking strength and elongation; water-repellency and water proofing; air-permeability resistance to pilling; and resistance to abrasion and seam slippage.

As well as being defined and tested, each performance characteristic in a fabric must meet the minimum quality standards MQS,[4] which are defined according to the different clothing items, that is, of different end-usage categories. In this chapter, unless otherwise stated, the quality standard itemised for all types of clothing is of a fairly high, but reasonable, level (Bona, 1994). If, for technical reasons, suppliers cannot guarantee these minimum values, it is important that they inform the purchaser accordingly, specifying the values they can guarantee and obtaining acceptance for these.

8.4.1 Colour fastness following exposure to light

The colour fastness following exposure to light of a material is defined as the level of change in colour it undergoes when exposed to light (ISO 105 B02:1994). This is measured using a specimen of the fabric to be tested. The specimen and a range of eight blue wool standards are simultaneously exposed to artificial light in an apparatus fitted with a xenon arc fading lamp. The humidity in the apparatus is controlled. Blue wool references are identified by the number 1 (very low colour fastness) to 8 (very high colour fastness), with each approximately double the fastness of the one below it. The term ‘change in colour’ includes changes in hue, chromatic characteristics, lightness or combination of these characteristics of colour (ISO 105-B01:1994). The minimum acceptable quality standards for colour fastness following exposure to light are shown in Table 8.1.

8.4.2 Colour fastness following artificial weathering

The colour fastness following artificial weathering of a material is defined as the level of colour change it undergoes when exposed to artificial weather conditions (ISO 105 B04:1994). This is measured using a specimen of the fabric to be tested. The specimen and a range of eight blue wool standards are simultaneously exposed to simulated weather conditions in an apparatus

[4] **Minimum quality standards MQS** correspond to minima, which means that no tolerance can be accepted.

Table 8.1 The minimum quality standards for fabric colour fastness following exposure to light compared with the European blue wool standard (DTB, 2006)

Trousers, shorts	Skirts	Jackets	Coats	Knitwear	Anoraks, skiwear, sportswear	Pyjamas, nightwear	Shirts, dresses, blouses	Lingerie	Swimwear	Lining
Colour fastness rating										
5	5	5	5	5	5	4	5	4	5	4

Table 8.2 The minimum quality standards for fabric colour fastness following artificial weathering compared with the European blue wool standard (DTB, 2006)

Trousers, shorts	Skirts	Jackets	Coats	Knitwear	Anoraks, skiwear, Sportswear	Pyjamas, nightwear	Shirts, dresses, blouses	Lingerie	Swimwear	Lining
Colour fastness rating										
5	5	5	5	5	5	4	5	4	5	4

fitted with a xenon arc fading lamp. Colour fastness is assessed by comparing the change in colour of the test specimen with that of the references. This method can also be used to determine whether a textile is wet light-sensitive. The minimum acceptable quality standards for colour fastness following artificial weathering are shown in Table 8.2.

8.4.3 Colour fastness following dry-cleaning using perchloroethylene

The colour fastness following dry-cleaning of a material is defined as the level of change in colour and/or the staining that the dyed fabric undergoes when exposed to perchloroethylene (ISO 105 D 01:2010). This is measured using a specimen of the fabric to be tested. The specimen is packed in a cotton fabric bag with non-corrodible steel discs and treated in laboratory washing equipment with a cleaning solvent for 30 min at 30°C. After drying, the change in colour of the sample is assessed using the grey scale for determining changes in colour. In accordance with ISO 105-A02: 1993, the

Table 8.3 The minimum quality standards for fabric colour fastness following dry-cleaning using perchloroethylene (DTB, 2006)

Trousers, shorts	Skirts	Jackets	Coats	Knitwear	Anoraks, skiwear, sportswear	Pyjamas, nightwear	Shirts, dresses, blouses	Lingerie	Swimwear	Lining
Colour fastness rating										
4	4	4	4	4	4	4	4	4	4	4

scale consists of five pairs of non-glossy grey chips (or swatches of grey cloth). Starting from a neutral grey, the second chip or swatch in each pair is increasingly lighter in colour, showing increasing colour contrasts. The pairs have the following fastness ratings:

- 5: very good – no visual change
- 4: good – trace
- 3: fairly good – some visual change
- 2: moderate – pronounced visual change
- 1: poor – major visual change

This scale may be augmented by chips or swatches with half-step fastness ratings (4–5, 3–4, 2–3 and 1–2), giving a nine-step scale. The minimum acceptable quality standards for colour fastness following dry-cleaning using perchloroethylene are shown in Table 8.3.

8.4.4 Colour fastness following perspiration

The colour fastness following perspiration of a material is defined as the level of change in colour and/or the staining that the dyed fabric undergoes when exposed to perspiration (ISO 105 E04:2008). This is measured using a specimen of the fabric to be tested. The specimen is brought into contact with white reference fabrics and then immersed in two solutions of histidine (one solution is acid, the other alkaline) and placed between two templates under a specified pressure in a test device, the so-called 'perspirometer'.[5] The perspirometer is then placed during 4 h in an with a temperature of 37°C. After the treatment the specimens are dried. The change in colour of

[5] **Perspirometer** is an instrument for testing colour fastness to perspiration. It is used for determining the resistance of the colour of textiles of all kinds and in all forms to the effect of human perspiration.

Table 8.4 The minimum quality standards for fabric colour fastness following perspiration (DTB, 2006)

Trousers, shorts	Skirts	Jackets	Coats	Knitwear	Anoraks, skiwear, sportswear	Pyjamas, nightwear	Shirts, dresses, blouses	Lingerie	Swimwear	Lining
Colour fastness rating										
4	4	4	4	4	4	4	4	4	4	3–4
Rate of staining										
4	4	4	4	4	4	4	4	4	4	3–4

the specimen under test is assessed using the grey scale for testing change in colour; the staining to the reference fabrics is assessed using the grey scale for assessing staining. The minimum acceptable quality standards for colour fastness following perspiration are shown in Table 8.4.

If the clothing is made up of white or light-coloured parts next to dark ones, the value of rate of staining must be 4–5 or higher and dark colours must not bleed to light ones. The clothing manufacturer should specify this standard when drawing up the contract.

8.4.5 Colour fastness following washing

The colour fastness following washing of a material is defined as the level of change in colour and/or the staining following washing (ISO 105 C06:2010, ISO 105 C08:2010 and ISO 105 C09:2001). This is measured using a specimen of the fabric to be tested. The specimen is brought into contact with white reference fabrics and washed in laboratory washing equipment for a predetermined time in a washing solution containing a specified detergent. The temperature of the wash varies according to the material. After rinsing and drying the change in colour of the specimen is assessed using the grey scale for measuring colour change (in accordance with ISO 105-A02: 1993). The staining to the reference fabrics is assessed using the grey scale for measuring colour staining. The minimum acceptable quality standards for colour fastness following washing for all washable fabrics and linings are shown in Table 8.5.

If the clothing is made up of white or light-coloured parts next to dark ones, the value of rate of staining must be 4–5 or higher, and dark colours must not bleed to light ones. The clothing manufacturer should specify this standard when drawing up the contract.

Table 8.5 The minimum quality standards for colour fastness following washing for all washable fabrics and linings (DTB, 2006)

Trousers, shorts	Skirts	Jackets	Coats	Knitwear	Anoraks, skiwear, sportswear	Pyjamas, nightwear	Shirts, dresses, blouses	Lingerie	Swimwear	Lining
Colour fastness rating										
4	4	4	4	4	4	4	4	4	4	4
Rate of staining										
4	4	4	4	4	4	4	4	4	4	4

8.4.6 Colour fastness following pressing or ironing

The colour fastness following the pressing or ironing of a material is defined as the level of change in colour and/or the staining of the adjacent fabric after hot pressing (ISO 105 X11:1994). A specimen of the fabric is used for testing and tests can be carried out when the textile is dry, when it is wet, or when it is damp. The end-use of the textile usually determines which test should be made in each case. A dry specimen is used for dry pressing, a dry specimen covered with a wet cotton adjacent fabric is used for damp pressing, and a wet specimen covered with a wet cotton adjacent fabric is used for wet pressing. All are pressed with a heating device at a specified temperature and pressure for a specified time. After the treatment the change in colour of the specimen is assessed by comparison with the appropriate grey scale (in accordance with ISO 105-A02: 1993), both immediately and after the specimen has been kept for four hours in the standard atmosphere designated for such tests. The minimum acceptable quality standards for colour fastness following pressing or ironing are shown in Table 8.6.

8.4.7 Colour fastness following rubbing

The colour fastness to rubbing of a material is defined as the resistance of colour in textiles to rubbing off and staining other materials (ISO 105 X12:2001). A specimen of the fabric is used for testing. Two tests are carried out using a dry and wet rubbing cloth. Specimens are tested in both the warp and the weft direction. Dry rubbing and wet rubbing are both tested. The staining to the reference fabrics is assessed using the grey scale for assessing

Table 8.6 The minimum quality standards for colour fastness following pressing or ironing (DTB, 2006)

Trousers, shorts	Skirts	Jackets	Coats	Knitwear	Anoraks, skiwear, sportswear	Pyjamas, nightwear	Shirts, dresses, blouses	Lingerie	Swimwear	Lining
Colour fastness rating										
4	4	4	4	4	4	4	4	4	4	3–4
Rate of staining										
4	4	4	4	4	4	4	4	4	4	3–4

Table 8.7 The minimum quality standards for colour fastness following rubbing (DTB, 2006)

Trousers, shorts	Skirts	Jackets	Coats	Knitwear	Anoraks, skiwear, sportswear	Pyjamas, nightwear	Shirts, dresses, blouses	Lingerie	Swimwear	Lining
Rate of staining: dry rubbing 4′										
Rate of staining: wet rubbing 3–4″										

staining in accordance with ISO 105-A03: 1993. The minimum acceptable quality standards for colour fastness to pressing or ironing are shown in Table 8.7.

8.4.8 Breaking strength and elongation

The breaking strength and elongation[6] of clothing fabrics are considered to be unacceptable if they are lower than the necessary minimum values for a particular end-use or the values specified in the contract or, in the

[6] **Elongation** – ratio of the extension (increase in length of a test specimen produced by a force; it is expressed in units of length) of a test specimen to its initial length, expressed as a percentage.

absence of these, typical sample values (EN ISO 13934–1:1999). The procedure for determining the maximum force and elongation of a textile fabric is to test specimen fabrics using a strip method. The specimens are tested in the standard atmosphere for testing in the wet state. The test is mainly applied to woven textile fabrics. It can be applied to fabrics produced using other techniques, but is not normally applied to woven elastic fabrics, geotextiles, non-wovens, coated fabrics, textile-glass woven fabrics, or fabrics made from carbon fibres. The minimum acceptable quality standards for the breaking strength and elongation of a material are shown in Table 8.8.

8.4.9 Seam slippage: fixed seam opening method and fixed load method

Seam slippage[7] is defined as the tendency of the warp and weft yarns in a woven fabric to slip over one another. A fabric is considered faulty due to seam slippage when there is a displacement of the yarn used for the fabric due to a force exerted perpendicularly to the seam, which produces an opening parallel to the seam.[8] The stitched seam slippage resistance of yarns in a seam in woven fabrics can be determined using either a fixed seam opening method – Part 1 (ISO 13936–1:2004) or a fixed load method – Part 2 (ISO 13936–2:2004).

Fixed seam opening method

Using this method tests are made until a predetermined fixed seam opening (to be agreed upon between parties) is reached. The necessary force to achieve this opening is then administered. The test report includes the average seam opening force (in newtons) for the specified seam opening (2 mm, 3 mm, 4 mm, 5 mm and 6 mm) for warp and weft slippage. This method is not suitable for stretch fabrics or for industrial fabrics, for example, beltings. The minimum acceptable quality standards for seam slippage in a material using the fixed seam method are shown in Table 8.9.

---

[7] **Seam slippage,** as tendency of warp and weft yarn in a woven fabric to slip, is a fabric property and should not be confused with seam strength. Warp slippage is warp yarns slipping over weft yarns, that is, the warp yarns are horizontal (at right angles) to the direction of pull; weft slippage is weft yarns slipping over warp yarns, that is, the weft yarns are horizontal (at right angles) to the direction of pull.

[8] If the seam of fabric breaks down and the slippage cannot be measured, this shall be recorded as a failure.

Table 8.8 The minimum quality standards for the breaking strength and elongation of a material (DTB, 2006)

Trousers, shorts	Skirts	Jackets	Coats	Knitwear	Anoraks, skiwear, sportswear	Pyjamas, nightwear	Shirts, dresses, blouses	Lingerie	Swimwear	Lining
Full fit										
Breaking strength F, in N										
250	250	200	200	*	250	180	180	180	220	180
Elongation, in %										
12.5–55	12.5–55	12.5–40	12.5–55	*	12.5–55	12.5–40	12.5–40	12.5–40	12.5–40	7.5–32.5
Tight fit										
Breaking strength F, in N										
300	300	200	200	*	250	220	220	220	220	220
Elongation, in %										
12.5–55	12.5–55	12.5–40	12.5–55	*	12.5–55	12.5–55	12.5–55	12.5–55	12.5–40	7.5–32.5

* Test not applicable on this product

Table 8.9 The minimum quality standards for seam slippage in a material using the fixed seam method (DTB, 2006)

Trousers, shorts	Skirts	Jackets	Coats	Knitwear	Anoraks, skiwear, sportswear	Pyjamas, nightwear	Shirts, dresses, blouses	Lingerie	Swimwear	Lining
Full fit Seam opening = 4 mm										
At 140 N load	At 140 N load	At 120 N Load	At 140 N load	*	At 140 N load	At 100 N load	At 110 N load	At 110 N load	At 140 N load	At 100 N load
Tight fit Seam opening = 4 mm										
At 160 N load	At 160 N load	At 120 N Load	At 140 N load	*	At 140 N load	At 120 N load	At 120 N load	At 120 N load	At 140 N load	At 120 N load

* Test not applicable to this product.

Fixed load method

Using this method tests are made until a predetermined fixed load (to be agreed between parties) is reached. The load applied can therefore vary, but the standard loads are as follows:

- 60 N – for fabrics with α mass ≤220 g m^2,
- 120 N – for fabrics with a mass >220 g m^2
- 180 N – for fabrics for furnishing.

The opening is then measured. The test report includes the mean warp slippage and the mean weft slippage concerning the load applied. This method is suitable for all clothing and upholstery woven fabrics, and stretch fabrics (including those containing elastomeric yarn). It is not suitable for industrial fabrics, for example, beltings. The minimum acceptable quality standards for seam slippage in a material using the fixed load method are shown in Table 8.10.

8.4.10 Resistance to abrasion

A fabric's resistance to abrasion is defined as faulty if the fabric wears out too quickly following normal use (ISO 12947–2:1998). The level of abrasion resistance in a fabric is determined using the Martindale method – Part 2: Determination of specimen breakdown. This method can be used to determine the level of breakdown due to abrasion in specimens from all textile fabrics, including non-wovens, apart from fabrics for which the specifier has indicated that their end-use requires a low abrasion wear life. Corduroy and pile fabrics are first tested on the reverse side of the fabric and then on the front of the fabric, according to the procedure described in Appendix A.2 of ISO 12947–2:1998. The minimum acceptable quality standards for fabric abrasion resistance are shown in Table 8.11.

8.4.11 Resistance to pilling

A fabric's resistance to pilling (the generation of pills, or clumps of entangled fibres, over the surface of the fabric) is defined as faulty if the fabric tends to pill quickly and the pills remain on the cloth (ISO 12945–2:2000). A textile fabric's resistance to pilling and surface change is determined using a modified Martindale method: Determination of fabric propensity to surface fuzzing and to pilling – Part 2. The specimen's resistance to pilling is assessed according to the following grading scheme:

- Grade 5: no visual change
- Grade 4: slight surface fuzzing and/or pilling

Table 8.10 The minimum quality standards for seam slippage in a material using the fixed load method (DTB, 2006)

Trousers, shorts	Skirts	Jackets	Coats	Knitwear	Anoraks, skiwear, sportswear	Pyjamas, nightwear	Shirts, dresses, blouses	Lingerie	Swimwear	Lining
Full fit										
Seam opening by fixed load										
120 N opening 3 mm	120 N opening 3 mm	120 N opening 4 mm	120 N opening 4 mm	*	120 N opening 4 mm	60 N opening 3 mm	60 N opening 3 mm	60 N opening 3 mm	60 N opening 3 mm	60 N opening 3 mm
Tight fit										
Seam opening by fixed load										
120 N opening 2 mm	120 N opening 2 mm	120 N opening 3 mm	120 N opening 3 mm	*	120 N opening 3 mm	60 N opening 2 mm	60 N opening 2 mm	60 N opening 2 mm	60 N opening 2 mm	60 N opening 3 mm

* Test not applicable to this product.

Table 8.11 The minimum quality standards for fabric abrasion resistance (DTB, 2006)

Trousers, shorts	Skirts	Jackets	Coats	Knitwear	Anoraks, skiwear, sportswear	Pyjamas, nightwear	Shirts, dresses, blouses	Lingerie	Swimwear	Lining
Pressure 9kPa										
20.000 revs.	20.000 revs.	16.000 revs.	16.000 revs.	8.000 revs.*	16.000 revs.	10.000 revs.	12.000 revs.	10.000 revs.	20.000 revs.	10.000 revs.

* Depending on type of article (from T-shirt till jumper/sweater).

Table 8.12 The minimum quality standards for fabric pilling resistance (DTB, 2006)

Trousers, shorts	Skirts	Jackets	Coats	Knitwear	Anoraks, skiwear, sportswear	Pyjamas, nightwear	Shirts, dresses, blouses	Lingerie	Swimwear	Lining
Woven fabrics				Woven fabrics with raised surface			Knitwear			
After 125 revolutions: 4 After 500 revolutions: 4 After 1000 revolutions: 4 After 2000 revolutions: 4				After 125 revolutions: 3–4 After 500 revolutions: 3 After 1000 revolutions: 2–3			After 125 revolutions: 3–4 After 500 revolutions: 3 After 1000 revolutions: 2–3			

- Grade 3: moderate surface fuzzing and/or pilling
- Grade 2: distinct surface fuzzing and/or pilling
- Grade 1: dense surface fuzzing and/or pilling

The minimum acceptable quality standards for fabric abrasion resistance are shown in Table 8.12.

8.4.12 Dimensional stability following washing

A fabric which will be sold as washable must maintain its dimensions after washing. These fabrics are tested according to two standards, ISO 5077:2007 and EN ISO 6330:2000:

- ISO 5077:2007 is designed for determining the level of dimensional change[9] in fabrics, garments or other textile articles when subjected to an appropriate combination of specified washing and drying procedures. The method is applicable to all washable fabrics and garments. In the case of textile articles or deformable materials, it is necessary to exercise all possible caution in the interpretation of the results.

[9] **Dimensional change** – when a fibre absorbs moisture, its dimensions change; there is a swelling both lengthways and crossways caused by the insertion of molecules of water in the polymer structure (Bona, 1994).

Table 8.13 The minimum quality standards for fabric dimensional stability following washing (DTB, 2006)

Trousers, shorts	Skirts	Jackets	Coats	Knitwear	Anoraks, skiwear, sportswear	Pyjamas, nightwear	Shirts, dresses, blouses	Lingerie	Swimwear	Lining
Length										
–2%	–2%	*	–2%	–6% +2%	–3%	–2%	–2%	–2%	–2%	–3%
Width										
–2%	–2%	*	–2%	–6% +2%	–3%	–2%	–2%	–2%	–2%	–3%

* Test not applicable to this product.

- EN ISO 6330:2000 is designed for specifying domestic washing and drying procedures for textile testing. The procedures are applicable to textile fabrics, garments and/or other textile articles, which are subjected to appropriate combinations of domestic washing and drying procedures.

The minimum acceptable quality standards for fabric dimensional stability following washing are shown in Table 8.13.

8.4.13 Dimensional stability following dry-cleaning

Fabrics intended for dry-cleaning must maintain their dimensions following this procedure. Fabrics are tested according to the ISO 3175–1:2010 standard Dry-cleaning and finishing – Part 1: Method for assessing the cleanability of textiles and garments.

Dry-cleaning tests are carried out using a commercial dry-cleaning machine. The fabric and garment properties likely to change following dry-cleaning and finishing are identified, and methods for assessing these changes using existing international standards are given where appropriate. Other properties which are also important, but for which no international standard methods of assessment are available, are also indicated, in annex A, together with advice on how to proceed with their assessment. It is recommended that comments on these properties should be included in the test report. Tests involve three dry-cleaning cycles using perchloroethylene

Table 8.14 The minimum quality standards for fabric dimensional stability following dry-cleaning (DTB, 2006)

Minimum quality standards (DTB, 2006)										
Trousers, shorts	Skirts	Jackets	Coats	Knitwear	Anoraks, skiwear, sportswear	Pyjamas, nightwear	Shirts, dresses, blouses	Lingerie	Swimwear	Lining
Length										
1.5%	1.5%	1.5%	1.5%	2.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%
Width										
1.5%	1.5%	1.5%	1.5%	2.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%

(in a charged bath) in an industrial dry-cleaning machine. The minimum acceptable quality standards for fabric dimensional stability following dry-cleaning are shown in Table 8.14.

8.4.14 Water-repellency

Fabrics with insufficient water-repellent properties when tested according to ISO 4920:1981 are considered faulty. The standard specifies a spray test method for determining the resistance of any fabric – which may or may not have been given a water resistance or water-repellent finish – to surface wetting by water. This test is not intended for use in predicting the rain penetration resistance of fabrics, since it does not measure the penetration of water through the fabric. The spray rating, the measure of the resistance of a fabric surface to wetting, is determined by comparing the appearance of a specimen with standard reference photographs. An ISO spray test rating chart based on AATCC photographs is available commercially. The five-step scale is:

1: wetting of the whole of the sprayed surface
2: wetting of half of the sprayed surface
3: wetting of small discrete areas of the sprayed surface
4: no wetting of, but adherence of small drops to, the sprayed surface
5: no wetting of and no adherence of small drops to the sprayed surface

The minimum acceptable quality standards for water-repellency in fabrics are shown in Table 8.15.

Table 8.15 The minimum quality standards for water-repellency in fabrics (DTB, 2006)

Trousers, shorts	Skirts	Jackets	Coats, rainwear	Knitwear	Anoraks, skiwear, sportswear	Pyjamas, nightwear	Shirts, dresses, blouses	Lingerie	Swimwear	Lining
New										
*	*	*	5	*	5	*	*	*	*	*
After care treatment										
*	*	*	3	*	3	*	*	*	*	*

* Test not applicable to this product.

8.4.15 Air permeability

Fabrics with insufficient air-permeability properties when tested according to the ISO 9237:1995 standard are considered faulty. The standard describes a method for measuring the permeability of fabrics to air, and that is applicable to most types of fabric,[10] including industrial fabrics for technical purposes, non-wovens and built-up textile articles that are permeable to air. This method is intended to determine the rate of air flow passing perpendicularly through a given area of fabric. The rate of air flow is measured at a given pressure difference across the fabric test area. The minimum acceptable quality standards for air permeability in fabrics are shown in Table 8.16.

8.4.16 Waterproofness

The waterproofness of fabrics is tested according to two standards, ISO 811:1981 and EN 343:2003:

[10] **Fabrics** with different surface textures on either side can have a different air permeability depending upon the direction of air flow. For woven fabric, yarn twist also is important. As twist increases, the circularity and density of the yarn increases, thus reducing the yarn diameter and the cover factor and increasing the air permeability. Yarn crimp and weave influence the shape and area of the interstices between yarns and may permit yarns to extend easily. Such yarn extension would open up the fabric, increase the free area, and increase the air permeability.

Table 8.16 The minimum quality standards for air permeability in fabrics (DTB, 2006)

Trousers, shorts	Skirts	Jackets	Coats, rainwear	Knitwear	Anoraks, skiwear, sportswear	Pyjamas, nightwear	Shirts, dresses, blouses	Lingerie	Swimwear	Lining
Depending on requirements										
*	*	*	25 mm/s (l/m²s)	*	25 mm/s (l/m²s)	*	*	*	*	*

* Test not applicable to this product.

- The ISO 811:1981 standard test involves a hydrostatic pressure test designed to determine the level of the fabric's resistance to water penetration. The method is primarily intended for dense fabrics, for example, duck fabrics (canvas), tarpaulins and tents. Specimens are subjected to a steadily increasing pressure of water on one side under standard conditions, until penetration occurs in three places. The water pressure may be applied from below or from above the test specimen. The hydrostatic head supported by the fabric is an effective measure of the fabric's resistance to the passage of water through it.
- The EN 343:2003 standard specifies the requirements for protective clothing against the effects of precipitation (e.g. rain and snow), fog, ground humidity and wind. The testing of rainproofness of ready-made garments is excluded from this standard at this time, because a separate test method for this property is currently being prepared. Garments according to this standard often also offer protection against the cold and therefore also follow the EN 342 standard and have corresponding markings.

The minimum acceptable quality standards for waterproofness in fabrics are shown in Table 8.17.

8.5 Visible faults

These faults have a visible effect on a fabric, comprising all the disproportions within the structure of the textile material that interfere with its end-use. If these faults are not detected early, that is, during the manufacturing process, they can drastically affect the production process and the quality

Table 8.17 The minimum quality standards for waterproofness in fabrics (DTB, 2006)

Trousers, shorts	Skirts	Jackets	Coats, rainwear	Knitwear	Anoraks, skiwear, sportswear	Pyjamas, nightwear	Shirts, dresses blouses	Lingerie	Swimwear	Lining
Weather resistant										
*	*	*	130 mBar	*	130 mBar	*	*	*	*	*
Fashion										
*	*	*	80 mBar	*	80 mBar	*	*	*	*	*

Minimum quality standards (DTB, 2006)

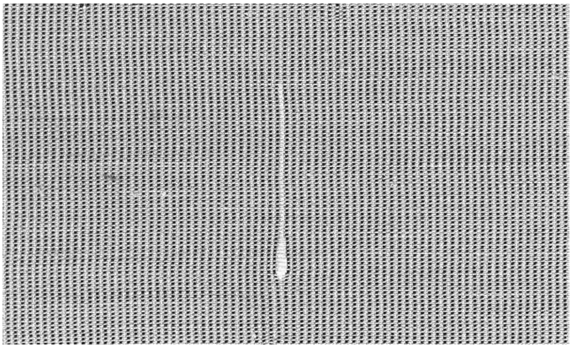
* Test not applicable to this product.

of the finished product. According to the BS 6395: 1983 standard, a fabric fault is defined as any feature within the usable width of a fabric that will downgrade the resultant garment. Visual faults can be categorised as spinning, weaving, dyeing, and processing faults, as well as mending faults, which arise due to mistakes during the fault removal or mending process (BS 6395: 1983; Tomar, 2010). A detailed presentation of visual faults or defects in or on fabrics can be found in the *Recommendations concerning characteristics and faults in fabrics to be used for clothing* (DTB, 2006).

8.5.1 Warp direction: thick or thin end, tight or slack end, missing end and double end

Material defects in the warp direction occur in the threads and are defined as follows:

- **Thick or thin end**: A warp thread that differs in diameter from the surrounding normal ends (Fig. 8.2).
- **Tight or slack end**: A warp thread, or part of a warp thread, that is tighter or slacker than the surrounding normal ends.
- **Missing or broken end**: The absence of a complete warp thread or part of a warp thread.



8.2 Thick end.

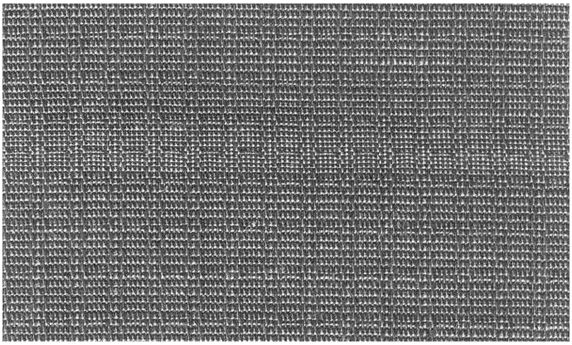
- **Double end**: A thread, or part of a thread, in the warp, which has accidentally been doubled.

Testing for faults in the warp direction is conducted using a simple visual assessment of the imperfections in the fabric to decide which would be unacceptable in a garment. The number or faults in the fabric are then counted and their lengths are measured. Faults are tolerated if the residual cloth width satisfies the terms of the contract (DTB, 2006).

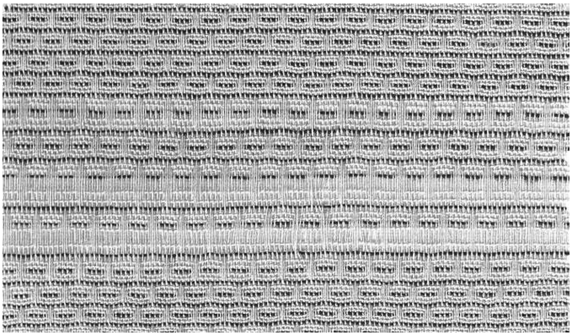
8.5.2 Weft direction: thick or thin pick, tight or slack pick, missing pick, broken pick, double pick and trailer

Material defects in the weft direction also occur in the threads and are defined as follows:

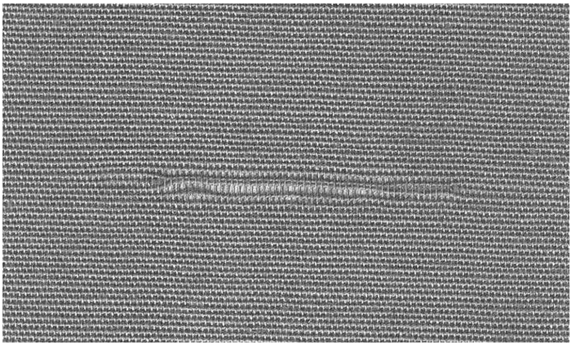
- **Thick or thin pick:** A weft thread that differs in diameter from the corresponding normal picks.
- **Tight or slack pick:** A weft thread, or part of a weft thread, that is tighter or slacker than the corresponding normal picks (Fig. 8.3).
- **Missing pick:** The unintentional omission of one complete pick across the full width of the cloth (Fig. 8.4).
- **Broken pick:** A pick that is inserted for only part of the cloth width (Fig. 8.5).
- **Double pick:** The thread or pieces of thread in the weft which form the woven structure but are accidentally doubled (Fig. 8.6).
- **Trailer:** Weft yarn that has been pulled inadvertently into the fabric during weaving (Fig. 8.7).



8.3 Tight pick.

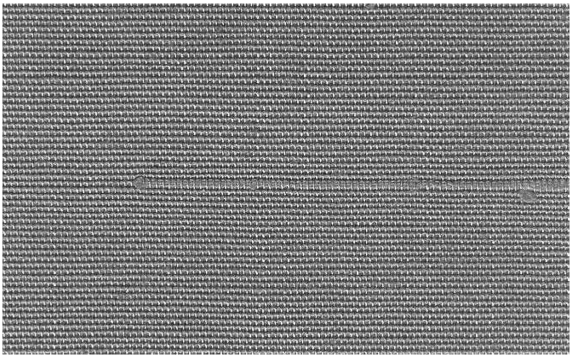


8.4 Missing picks.

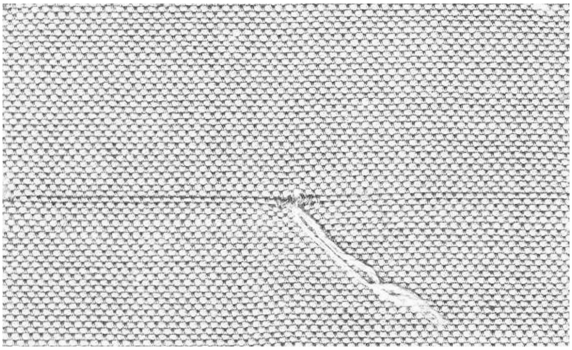


8.5 Broken pick.

As with the assessment of faults in the warp direction, testing for faults in the weft direction is also conducted using a simple visual assessment of the imperfections in the fabric that would be deemed unacceptable in a garment, followed by a measurement of their lengths. In this case however,



8.6 Double pick.

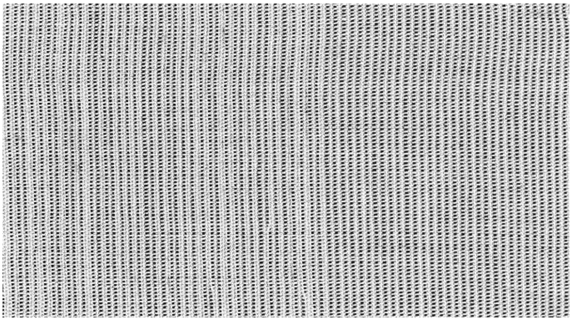


8.7 Trailer.

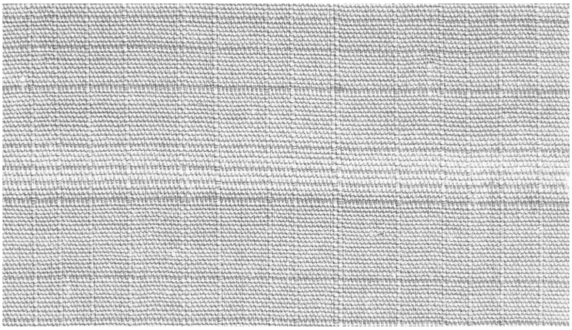
no tolerance is permitted for faults detected using this method of control (DTB, 2006).

8.5.3 Stripes in the warp

Stripes or streaks in the warp, which extend either for part of the warp direction or over its entire length and which show up as faults against the rest of the material, are considered to be faults in the fabric (Fig. 8.8). A visual assessment of the fabric and the measurement of the length of the stripes are sufficient tests to decide whether the imperfections would be unacceptable in a garment. Stripe faults are tolerated if the residual cloth width meets the terms of the contract (DTB, 2006).



8.8 Stripes in the warp.



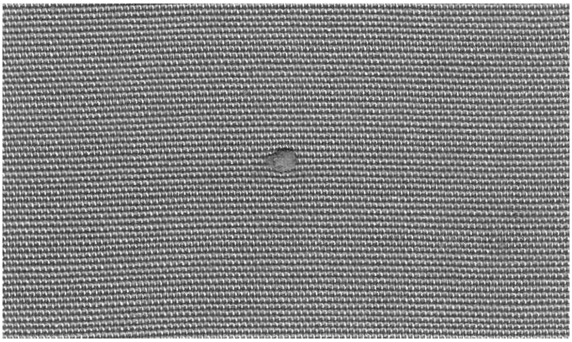
8.9 Bars in the weft.

8.5.4 Bars in the weft

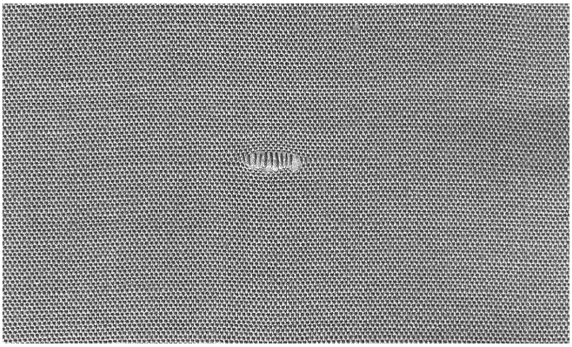
Bars in the weft are defined as streaks, which occur over either the full or part of the length of the weft direction and which show up against the rest of the piece (Fig. 8.9). Again, a visual assessment of the imperfections is used to decide whether they would be unacceptable in a garment. The length of the bars is also measured if they occur in a sequence. No tolerance is permitted for faults detected using this method of control (DTB, 2006).

8.5.5 Knot or slubs in the warp or weft threads

Knot or slubs in some of the weft or warp threads are considered to be faults when they are visible to an experienced person and when they spoil the appearance of the fabric (Fig. 8.10). This visual assessment is sufficient



8.10 Knot.



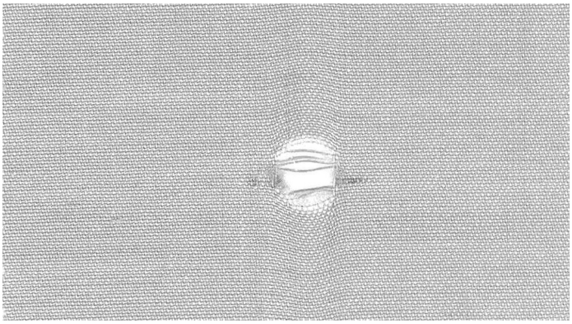
8.11 Burling.

to test whether the faults would be unacceptable in a garment and no tolerance is permitted for faults detected using this method of control (DTB, 2006).

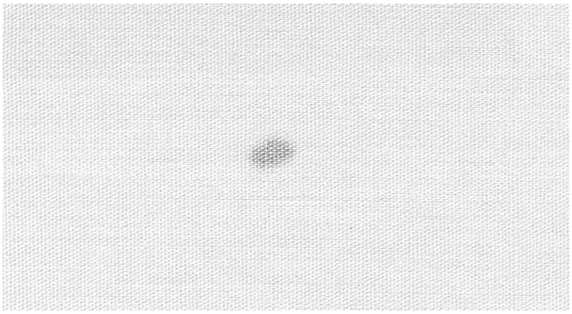
8.5.6 Faulty mending and burling, tears, holes and stains

Faults caused by mending and burling, tears, holes and stains are defined as follows:

- **Faulty mending**: poor appearance of repair on the surface of the fabric.
- **Faulty burling:** the presence of faults which have not been removed during burling (Fig. 8.11).



8.12 Hole.



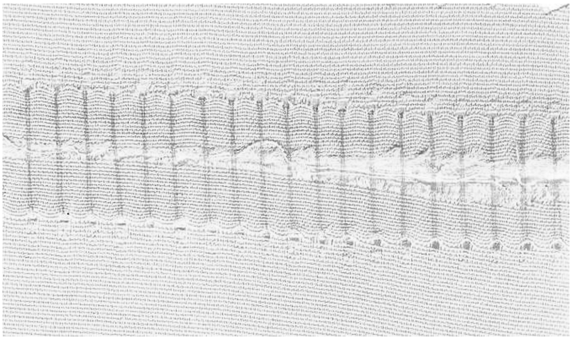
8.13 Stain.

- **Tears, cuts and holes:** various forms of cloth breakage (Fig. 8.12).
- **Stains:** areas of the cloth that have been contaminated with impurities (Fig. 8.13).

These types of faults are again tested using a visual assessment of the imperfections and the measurement of their length to ascertain whether they are unacceptable for use in a garment. No tolerance of these faults is permitted (DTB, 2006).

8.5.7 Fabric pieces cut in several parts

Fabric is deemed faulty if it is cut across the whole width in two or more parts, the total being equal to the required length (Fig. 8.14). Once it has been verified that the number of the separate parts together makes up the length ordered, no tolerance of this fault is permitted (DTB, 2006).



8.14 Pieces cut.

8.6 Care labelling of clothing and textile products

The durability[11] and maintenance of a textile product during its normal period of usage is of great importance. For this reason, many clothing manufacturers provide consumers with additional information regarding maintenance of their clothing, in order to help them get the most out of it for as long as possible. Maintenance is the ability of a textile and articles of clothing to remain in the same state of cleanliness, size, physical integrity and colour, as they were when purchased, taking into account wear, usage, and/or care procedures (Hatch, 1993). Care performed on the basis of the information given on the label provides a guarantee that the textile product will not be damaged. It does not, however, guarantee that all varieties of dirt and stains will be removed. The following sections consider those maintenance properties relating to the care labelling of clothing and textile products and provide recommendations for improved care labelling in the future.

8.6.1 Recommendations for care labelling

A care label is a permanent label or tag, containing regular[12] care information and instructions for the ordinary user of the product. It is attached or affixed in such a manner that it will not become separated from the product, and will remain legible during the useful life of the product (FTC, 2000). Care-label recommendations on an item of clothing includes various instructions regarding washing, bleaching, drying, ironing and dry-cleaning,

11 **Durability** is the ability of a textile to retain its physical integrity under conditions of mechanical stress for a reasonable period of time (Hatch, 1993).

12 **Regular care in this instance** means customary and routine care, not spot care.

by following standard procedures. When determining what to include on a care label, there are certain options to be considered, depending on the performance of the clothing. For example, if an article of clothing deteriorates during normal washing then dry-cleaning needs to be recommended. Additional care instructions are also advocated when labelling speciality clothing.

8.6.2 Care-labelling systems

Care labels provide information on the maximum permitted treatments and the proper care of clothing textiles. They are intended both for consumers and for those companies, such as laundrettes and dry-cleaners, responsible for the care of textiles. Care labelling is not mandatory at EU level, but at Member State level the situation varies. In most of the older Member States (EU-15 except Austria and Finland) and in Slovenia, Lithuania, Malta, and Cyprus, care labelling is optional, whereas many of the new Member States have mandatory care-labelling requirements (Euratex, 2007; IMCO, 2010).

Both the optional care-labelling systems applied by manufacturers and importers, and those legally required in the Member States where care labelling is mandatory, are generally based on the ISO 3758:2005 standard, which, in turn, is based on the care symbols developed by GINETEX.[13] These symbols are protected by a trademark owned by GINETEX (2010). In 1990, GINETEX allowed ISO to incorporate these symbols into the ISO 3758:2005 standard. The ISO 3758:2005, in turn, was adopted by CEN as a European standard EN ISO 3758 (IMCO, 2010). This means that there is effectively only one system in Europe, the GINETEXsystem / EN ISO 3758 standard. In 2012 a new, revised care-labelling standard, EN ISO 3758:2012, was published, which will replace the previous version. One of the main changes in the new standard, which will affect retailers and brands, is the revision of the appearance of the 'Do not bleach' symbol. This has now reverted to a lined version.

Several of the main EU trade partners have mandatory care-labelling systems, including the USA, Japan, Australia and China. The USA has had care-labelling legislation since 1971. The legislation has seen several amendments since then, with the current mandatory care-labelling system being in place since 2000. American care labels can be composed of either words

[13] **GINETEX** (Groupement International d'Etiquetage pour l'Entretien dex Textiles), the International Association for Textile Care Labelling, was first founded in Paris 1963 following several International Symposiums for Textile Care Labelling at the end of the 1950s. GINETEX has devised an internationally applicable care-labelling system for textiles based on symbols. The pictograms used are registered trademarks and are the property of GINETEX.

or symbols, although words are most commonly used. As a minimum, they must include and be listed in the order of washing, bleaching, drying, ironing, and dry-cleaning instructions. Additional instructions can be provided for clarification purposes.

The care-labelling system in Japan is similar to that used in the USA. The symbols used are different, but they must also be in a certain order. That order is washing, bleaching, ironing, dry-cleaning, wringing and drying (Anon., 2012). In March 2009, a revised care-labelling standard came into effect in China. The new standard brought care-labelling instructions into alignment with the international care-label standard ISO 3758. The major changes necessary for this alignment were the sequence and shapes of symbols, as well as the introduction of additional symbols (Anon., 2009).

8.6.3 Care-labelling code using symbols

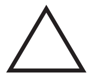
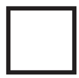
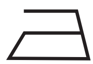
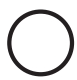
Care labelling, which states the level of regular care necessary for the ordinary use of the product, is determined by the International Standard ISO 3758:2012. This international standard establishes a system of graphic symbols, intended for use in the marking of textile articles, which provide information to prevent irreversible damage to the article during the textile care process and specifies the use of these symbols in care labelling.

The following domestic treatments are covered in care labelling:

- Washing – a process designed to clean textile articles in an aqueous bath. This operation may be carried out by machine or by hand.
- Bleaching – a process carried out in an aqueous medium before, during, or after washing and, which requires the use of an oxidising agent, including either chlorine or oxygen/non-chlorine products.
- Drying after washing – a process carried out on textile articles after washing to remove excess water (or moisture).
- Ironing – a process carried out on a textile article to restore its shape and appearance by means of an appropriate appliance using heat, pressure and possibly steam.
- Professional textile care – professional dry-cleaning and professional wet cleaning, excluding commercial laundering.

Five basic symbols and four additional symbols are provided to outline how a user should care for a particular item of clothing or textile product. The care label provides instructions on what to do and what not to do when cleaning or caring for the product. The basic care symbols with care instructions are shown in Table 8.18. This International Standard applies to all textile articles in the form in which they are supplied to the end user.

Table 8.18 The basic care symbols

Treatment	Description	Symbol	Instruction
Washing	For the washing processes, a washtub as shown		The symbol indicates whether domestic washing is possible and applies both to hand and machine washes
Bleaching	For the bleaching processes, a triangle as shown		The symbol indicates whether the article may or may not be bleached
Drying	For the drying processes, a square as shown		The square is the symbol of the drying process. The circle inside the square is a reference to tumble drying; the line(s) inside the square symbolises natural drying after the washing process
Ironing	For the ironing and pressing processes, a hand iron shape as shown		The dots indicate the temperature ranges for ironing
Professional textile care	For the professional dry-cleaning and professional wet cleaning processes (excluding commercial laundering), a circle		The symbol gives information on the possibility of professional dry or wet cleaning

8.7 Ecological labelling of clothing and textile products

The ecological awareness of consumers regarding textile products is increasing, and this has increased the pressure on textile and clothing producers to produce environmental and human-friendly products that are less harmful both to nature and to human health. In order to address this concern, the human ecological quality objectives for textiles and clothing were developed at the beginning of the 1980s. These objectives are based primarily on textile ecology, which connects four significant areas (Loy, 1993):

- Production ecology, which is concerned with the effects of production processes on people and the environment,

- Human ecology,[14] which is concerned with the effects of textiles and the chemicals contained within them on the health and well-being of the consumer. In particular, the harmful substances present in clothes, which can evoke different reactions in people; for example eczema, which can occur due to the physical irritation that occurs through friction with too tight-fitting clothing, or through heat and moisture,
- Performance ecology, which deals with issues concerning textiles when in use, that is, the effects of washing, dry-cleaning and the care cycle on the environment, and
- Disposal ecology, which solves problems relating to the disposal of textiles, such as recycling.

The mid-1980s saw increased significance being attached to the issue of the potentially harmful effects of textile and clothing products. In 1987, in collaboration with medical experts, the Austrian Textile Research Institute ÖTI (Institut für Ökologie, Technik und Innovation GmbH) developed a testing and certification system under the name *Tested to ÖTN 100 Standard,* in order to verify the harmlessness of textiles from the viewpoint of human ecology.

In order to establish these activities on an international basis, the ÖTI formed the 'International Oeko-Tex® Association' in conjunction with the Hohenstein Research Institute in Germany, which, since 1991, has been carrying out pollution analyses in accordance with the so-called 'Hohensteiner Oeko-Check'. Their combined experience was utilised by introducing the Oeko-Tex 100 Standard in 1992 (McCarthy and Burdett, 1998). In 1992, an EU Regulated Eco-label was announced under Council Regulation (EEC) No. 880/92 on a Community Award Scheme. This regulation established an optional eco-label scheme intended to promote the design, production, marketing and use of those products that have a reduced environmental impact during their entire life cycle, and to provide consumers with better information on the environmental impacts of products.

The Oeko-Tex® Standard 100, which was established as a response to the needs of the general public, and updated[15] on 1st April 2012, is a normative

[14] **Human ecology** deals with the idea that clothing and other textile products in close contact with human skin should not cause any harm to people through physical contact, respiration or digestion. The main objective of human ecology was to determine whether any toxic substance exist in a textile product, taking into account where it is used, and at what concentration these substance were found in a product through a series of analyses (Guner and Yucel, 2005).

[15] The Oeko-Tex® Association has updated the applicable test criteria and limit values for testing textiles for harmful substances according to Oeko-Tex® Standard 100 at their annual meeting, with effect as of 1 January 2012. The new requirements will come into force on 1 April 2013.

8.15 Oeko-Tex® standard 100 mark.

document. It specifies both the general and specific conditions for granting authorisation regarding the marking of textiles with the Oeko-Tex® standard mark, as shown in Fig. 8.15. The standard is applicable for textile and leather products, and articles at all levels of production, including textile and non-textile accessories (Oeko-Tex 100:2012).

Harmful substances, within the context of the Oeko-Tex® Standard 100, refers to: substances that may be present in a textile product or accessory and, which exceed the maximum amount; substances that evolve during normal and prescribed usage and exceed the maximum amount; substances which may have a negative effect on people during normal and prescribed usage; and, substances, which may, according to current scientific knowledge, be injurious to human health.

The Oeko-Tex® Standard 100 mark, *Confidence in Textile – Tested for harmful substances according to Oeko-Tex® Standard 100,* refers to a marking that can be applied to a textile product or to an accessory, providing the general and special conditions for granting authorisation are fulfilled and if authorisation to use this mark on a product has been granted by an institute or an authorised certification agency (Oeko-Tex 100:2012). The mark, *Confidence in Textile – Tested for harmful substances according to Oeko-Tex® Standard 100,* is not a quality label. This mark only relates to the as-produced state of the textile. It denotes that the marked product fulfils the conditions specified in this standard, that is, that the product has been tested for harmful substances that are prohibited or regulated by the standard and for chemicals that are known to be harmful to health along with other parameters that are included as a precautionary measure for safeguarding health. A product class, in the context of this standard, is a group of different articles categorised according to their utilisation, and according to how closely they come into contact with the consumers' skin. The product classes, which differ generally in the requirements that the products have to fulfil, are shown in Table 8.19 (Oeko-Tex 100:2012). The regular re-evaluation of the test parameters are based on current market and product developments, new toxicological findings and new legal requirements, as added in 2011.

The standard sets extremely stringent conditions for baby and toddler textile products; for example, the maximum value of formaldehyde

Table 8.19 The product classes according to Oeko-Tex® Standard 100

	The product classes	Definition
Product class I	Products for babies	Products for babies in the context of this standard are all articles, basic material and accessories, which are provided for the production of articles for babies and children up to the age of 36 months with the exception of leather clothing.
Product class II	Product with direct contact to skin	Article with direct contact to skin are those, which are worn with a large part of their surface in direct contact with the skin (e.g. blouses, shirts, underwear, mattresses, etc.).
Product class III	Product without direct contact to skin	Article without direct contact to skin are those, which are worn with only a little part of their surface in direct contact with the skin (e.g. stuffing, etc.).
Product class IV	Decoration material	Decoration material in the context of this standard are all articles including initial products and accessories, which are used for decoration such as table cloths, wall coverings, furnishing fabrics, and curtains, upholstery fabrics, and floor coverings.

content permissible is <16 ppm,[16] in the current version, the actual safe maximum for formaldehyde content being 20 ppm. 75 ppm is the formaldehyde limit for products that come in contact with the skin, such as bed linen, underwear, shirts, and blouses. Even products that do not come into continuous contact with the skin, such as outerwear (women's and men's suits, coats) and furnishings (table linen, decorative fabrics, curtains, furniture fabrics, and mattresses) are limited to formaldehyde content lower than the limit value of 300 ppm. Product specific requirements for certification, according to the Oeko-Tex® Standard 100 (Oeko-Tex 100:2012), are shown in Table 8.20, where they are given as limit values for testing textiles for harmful substances in the context of the product classes, which have to be fulfilled by each component.

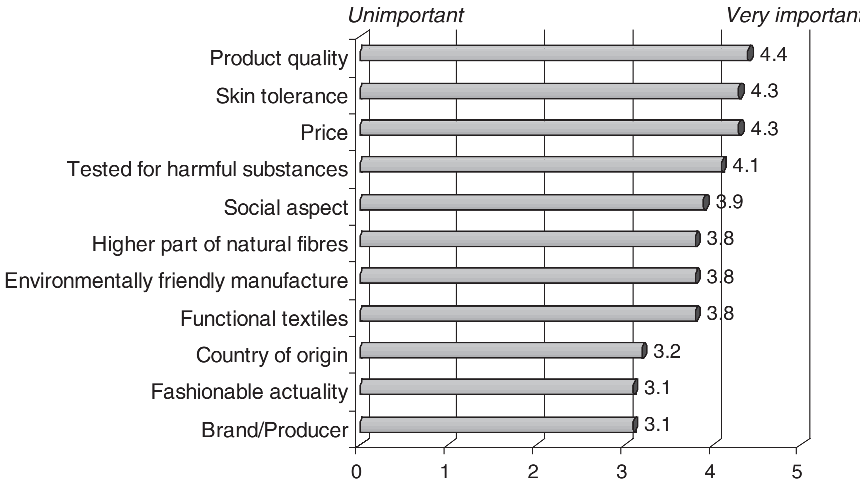
Eco-labelling is increasing worldwide as a differentiating factor in retail markets for textile and apparel purchases. For many consumers in target markets such as Europe or Japan, evidence that textile products are not harmful to health is becoming an increasingly important factor influencing their buying decisions. Over the last five years, a significant worldwide increase in the relevance of inspecting for harmful substances has been

[16] Ppm – abbreviation part(s) per million.

Table 8.20 The limit value of product specific requirements according to Oeko-Tex® Standard 100 (Oeko-Tex 100:2012)

Specific requirements	Limit values			
	I Products for babies	II Product with direct contact to skin	III Product without direct contact to skin	IV Decoration material
pH[a] value	4.0–7.5	4.0–7.5	4.0–9.0	4.0–9.0
Formaldehyde ($mg\ kg^{-1}$)				
Law 112	n.d.[b]	75	300	300
Extractable heavy metals {$mg\ kg^{-1}$)				
Sb (Antimony)	30.0	30.0	30.0	
As (Arsenic)	0.2	1.0	1.0	1.0
Pb (Lead)	0.2	1.0[c]	1.0[c]	1.0[3]
Cd (Cadmium)	0.1	0.1	0.1	0.1
Cr (Chromium)	1.0	2.0	2.0	2.0[d]
Co (Cobalt)	1.0	4.0	4.0	4.0
Cu (Copper)	25.0[5]	50.0[e]	50.0[e]	50.0[5]
Ni[f] (Nickel)	1.0	4.0	4.0	4.0
Hg (Mercury)	0.02	0.02	0.02	0.02
Heavy metals in digested sample[g] ($mg\ kg^{-1}$)				
Pb (Lead)	90.0	90.0[3]	90.0[3]	90.0[3]
Cd (Cadmium)	50.0	100.0[3]	100.0[3]	100.0[3]
Pesticides[h] ($mg\ kg^{-1}$)				
Incl. PCP/TeCP[i]	0.5	1.0	1.0	1.0
Chlorinated phenols[i] ($mg\ kg^{-1}$)				
Pentachlorphenol (PCP)	0.05	0.5	0.5	0.5
Tetrachlorphenol TeCP, sum	0.05	0.5	0.5	0.5

[a] Exceptions for products which must be treated wet during the further processing: 4.0–10.5 for foams: 4.0–9.0; for leather products in product class IV (coated or laminated): 3.5–9.0.
[b] n.d. corresponds according to 'Japanese Law 112' test method with an absorbance unit less than 0.05 respectively <16 $mg\ kg^{-1}$.
[c] Not a requirement for accessories made from glass.
[d] For leather articles 10.0 $mg\ kg^{-1}$.
[e] Not a requirement for accessories made from inorganic materials.
[f] Including the requirement by EC-Directive 94/27/EC.
[g] Applicable to all non-textile accessories and components as well as for spun dyed fibres and articles containing pigments.
[h] For natural fibres only.
[i] The individual substances are listed in Appendix 5 of Oeko-Tex® Standard 100:2012.



8.16 Key issues in the purchase of textiles and clothing (IFH, 2012).

detected. These and other important aspects influencing the process of purchasing textiles and clothing are shown in Fig. 8.16 (IFH, 2012).

The spread and increased recognition of the OEKO-TEX® Standard 100 has meant that the OEKO-TEX® label has become almost like a brand name, and is actively sought after by consumers. The sign *Confidence in Textile – Tested for harmful substances according to Oeko-Tex® Standard 100* is comprehensively protected as a trademark. On a worldwide basis there are applications or registrations about the label as a trademark (Oeko-Tex 100:2012). *Confidence in Textiles* is synonymous worldwide with responsible textile manufacture – from the raw materials to the finished product on the shelf. The Oeko-Tex certification system has become established as a fixed component in companies' quality management systems throughout the textile manufacturing chain, which is of equal benefit to manufacturers, retailers and consumers alike.

8.8 Conclusions

This chapter has reviewed current textile material testing, definitions and methods of measurement, as well as care labelling and eco-labelling. In reviewing textile material testing, particular attention has been paid to the quality characteristics of textile materials. The quality characteristics of a material are directly reflected in the quality of the finished product. It is particularly important to be aware of poor quality materials, since these result in poor product quality products and customer dissatisfaction. The standards establishing minimum performance criteria for materials reviewed in this chapter, together with the standards governing manufacturing and finished product quality in Chapter 4, provide the foundation for quality assurance in clothing production and are the basis for designing effective production operations.

The key elements for selecting the textile materials that best serve a specific end-use application, and that best match the performance criteria established by the consumer, are given through the presentation of the characteristics of material quality in this chapter; particularly, the physical characteristics and tolerance, as well as the performance characteristics and minimum quality standards. From an operative point of view, however, it is necessary to mention that the presented minimum quality standards for several performance characteristics are only recommendations concerning any characteristics and faults in those fabrics to be used for clothing, as a basis for the adoption of fabric specifications.

The essential purpose of all these quality standards and recommendations, whether from the point of view of the textile fabric producer or the clothing producer, is to establish and define the required quality level and performance characteristics for a textile material, so that it can be used for clothing. It is, however, clear that within these quality standards and recommendations there are also various possible and well-defined higher criteria, such as the fact that higher quality products often require a much higher degree of material quality characteristic definitions, are easier to maintain and have a reduced environmental impact during their entire life cycle. With increased awareness throughout the supply chain, it is possible to establish material quality characteristics which are more ethical, environmental and socially responsible.

8.9 References

Anon. (2009), 'China Revises the Textile Care Labelling System to Use Updated Symbols' – GB/T8685–2008, Saveguards, SGS *Consumer Testing services*, No. 075/09 May.

Anon. (2012), 'Care Labelling, Caring about the consumer beyond the label', © *Intertek*, 1–12.

Bona, M. (1994), *Textile Quality, Physical Methods of Product and Process Control*, Biella, Texilia.

BS 6395:1983 Method for numerical designation of fabric faults by visual inspection.

Chuter, A. (2002), *Quality Management in the Clothing and Textile Industry*, The Textile Institute.

Commission Directive 97/37/EC of 19 June 1997 adapting to technical progress Annexes I and II to Directive 96/74/EC of the European Parliament and of the Council on textile names (Text with EEA relevance), *Official Journal*, L **169**, 27 June 1997, 74–75.

Commission Directive 2004/34/EC of 23 March 2004 amending, for the purposes of adapting to technical progress, Annexes I and II to Directive 96/74/EC of the

European Parliament and of the Council on textile names, *Official Journal*, L **89**, 26 March 2004, 35.
Council Directive 94/27/EC5 (the 'Nickel Directive') of 30th June 1994, *Official Journal,* L **188**, 22 July 1994, 1.
Council Regulation (EEC) No 880/92 of 23 March 1992 on a Community eco-label award scheme, *Official Journal* L **099**, 11 April 1992, 0001–0007.
Directive 96/73/EC of the European Parliament and of the Council of 16 December 1996 on certain methods for the quantitative analysis of binary textile fibre mixtures. *Official Journal*, L **032**, 03 February 1997, 0001–0037.
Directive 96/74/EC of the European Parliament and of the Council of 16 December 1996 on Textile names. *Official Journal*, L **032**, 03 February 1997, 0038–0055.
DTB (2006), *Recommendations Concerning Characteristics and Faults in Fabrics to be Used for Clothing*, GermanFashion Modeverband Deutschland e.V., Dialog Textile-Bekleidung, Edition March 2006.
EN 343:2003 Protective clothing: Protection against rain.
EN 1049–2:1993 Textiles – Woven fabrics – Construction – Methods of analysis – Determination of number of threads per unit length, December 1993.
EN 1773:1996 Textiles – Fabrics – Determination of width and length, December 1996.
EN ISO 3758:2012 Textiles Care-labelling code using symbols.
EN 12127:1977 Textiles – Fabrics – Determination of mass per unit area using small sample, October 1977.
Euratex (2007), *Revised – Textile and Clothing Labelling – World Countries and Territories,* Brussels, Commercial Policy N° 65/2007, Industrial Strategy N°14/2007, Technical Clothing n° 27.
Fan, Q. (2005), *Chemical Testing of Textiles*, Woodhead Publishing Limited.
FTC (2000), *Care Labelling of Textile Wearing Apparel and Certain Piece Goods*, 16 CFR Part 423, Federal Trade Commission, September 1.
GINETEX (2010), 'How to label in a sustainable way?' *Newsletter 01,*© by GINETEX the international association for textile care labelling.
Guner, M. and Yucel, O. (2005), 'Environmental protection and waste management in textile and apparel sectors', *Journal of Applied Sciences*, **5** (10), 1843–1849.
Hatch, K. L. (1993), *Textile Science*. New York, West Publishing Company.
Houck, M. (2010), *Identification of Textile Fibers*, Woodhead Publishing Limited.
Hu, J. (2008), *Fabric Testing*, Woodhead Publishing Limited.
IFH (2012), *20 years of Oeko-Tex® Standard 100*, Project Report of a worldwide Consumer-Survey, Cologne, IfH Institut für Handelsforschung GmbH, April 2012
IMCO (2010), *Study on Labelling of Textile Products PE 429.992,* Policy department A: Economic and scientific policies, Internal market and consumer protection, IP/A/IMCO/ST/2009–11, Brussels, © European Parliament, January.
ISO 105-B01: 1994 Textiles – Tests for colour fastness – Part B01: Colour fastness to daylight.
ISO 105-B02:1994 Textiles – Tests for colour fastness – Part B02: Colour fastness to artificial light: Xenon arc fading lamp test.
ISO 105-B04:1994 Textiles – Tests for colour fastness – Part B04: Colour fastness to artificial weathering: Xenon arc fading lamp test.

ISO 105-C06:2010 Textiles – Tests for colour fastness – Part C06: Colour fastness to domestic and commercial laundering.
ISO 105-C08:2010 Textiles – Tests for colour fastness – Part C08: Colour fastness to domestic and commercial laundering using a non-phosphate reference detergent incorporating a low-temperature bleach activator.
ISO 105-C09:2001 Textiles – Tests for colour fastness – Part C09: Colour fastness to domestic and commercial laundering Oxidative bleach response using a non-phosphate reference detergent incorporating a low-temperature bleach activator.
ISO 105-D01:2010 Textiles – Tests for colour fastness – Part D01: Colour fastness to dry-cleaning using perchloroethylene solvent.
ISO 105-E04:2008 Textiles – Tests for colour fastness – Part E04: Colour fastness to perspiration.
ISO 105-X11:1994 Textiles – Tests for colour fastness – Part X11: Colour fastness to hot pressing.
ISO 105-X12:2001 Textiles – Tests for colour fastness – Part X12: Colour fastness to rubbing.
ISO 811:1981 Textile fabrics – Determination of resistance to water penetration – Hydrostatic pressure test.
ISO 1833:1977 Textiles – Binary fibre mixtures – Quantitative chemical analysis.
ISO 3175–1:2010 Textiles – Professional care, dry-cleaning and wet-cleaning of fabrics and garments – Part 1: Assessment of performance after cleaning and finishing.
ISO 3758:2005 Textiles – Care labelling code using symbols.
ISO 3758:2012 Textiles – Care labelling code using symbols.
ISO 3801:1977 Textiles – Woven fabrics – Determination of mass per unit length and mass per unit area.
ISO 3932:1976 Textiles – Woven fabrics – measurement of width of pieces.
ISO 3933:1976 Textiles – Woven fabrics – measurement of length of pieces.
ISO 4920:1981 Textiles – Determination of resistance to surface wetting (spray test). First edition.
ISO 5077:2007 Textiles – Determination of dimensional change in washing and drying.
ISO 5088:1976 Textiles – Ternary fibre mixtures – quantitative analysis.
ISO 5089:1977 Textiles – Preparation of laboratory test samples and test specimens for chemical testing.
ISO 6330:2000 Textiles – Domestic washing and drying procedures for textile testing.
ISO 7211–1:1984 Textiles – Woven fabrics – Construction – Methods of analysis – Part 1: Methods for the presentation of a weave diagram and plans for drafting, denting and lifting.
ISO 7211–2:1984 Textiles – Woven fabrics – Construction – Methods of analysis – Part 2: Determination of number of threads per unit length.
ISO 9237:1995 Textiles – Determination of the permeability of fabrics to air.
ISO 12945–2:2000 Textiles – Determination of fabric propensity to surface fuzzing and to pilling Part 2: Modified Martindale method.
ISO 12947–2:1998 Textiles – Determination of the abrasion resistance of fabrics by the Martindale method Part 2: Determination of specimen breakdown.
ISO 13934–1:1999 Textiles – Tensile properties of fabrics – Part 1: Determination of maximum force and elongation at maximum force using the strip method.

ISO 13936–1:2004 Textiles – Determination of the slippage resistance of yarns at a seam in woven fabrics – Part 1: Fixed seam opening method.

ISO 13936–2:2004 Textiles – Determination of the slippage resistance of yarns at a seam in woven fabrics – Part 2: Fixed load method.

Lorek, S. and Luca, R. (2003), *Towards Sustainable Market Strategies,* Wuppertal Institute for Climate, Environment and Energy, Wuppertal Papers, No. 130, June 2003.

LOY, W. (1993), 'Ökotextilien – Modewort oder Zukunftschance?' *Textil Praxis International*, Stuttgart, July/August, 599–603.

McCarthy, B. J. and Burdett, B. C. (1998), 'Eco-labelling and textile eco-labelling'. *Review of Progress in Coloration and Related Topic*, **28** (1), 61–70.

OEKO-TEX Standard 100 (2012), OEKO-TEX Zürich, Edition 04/2012.

Saville, B. (1999), *Physical Testing of Textiles*, Woodhead Publishing Limited.

Tomar, R. S. (2010), *Handbook of Worsted Wool and Blended Suiting Process*, Woodhead Publishing India PVT LTD.

Index