

ERWIN VON WASIELEWSKI

Project Knowledge Management

Systematic Learning with the
Project Comparison Technique

 Springer

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Erwin von Wasielewski

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Translated by Lore Mair

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Dedication

Shortly before this book went into print, my father Erwin von Wasielewski died at the age of 81. He was happy to know that by publishing his work in English, he was able to communicate his findings to virtually everyone interested, like himself, in understanding the underlying structure of things, in going towards one's overall goal with attention to every detail, and in dedication to one's work.

So this is to be a kind of memorial to my father. I would be glad to learn that it is not only looked at, like one in stone or steel, but brought to life, used, applied, maybe even by teaching others. That would fulfill everything my father was wishing for when he wrote it.

*Lore Mair,
Author's daughter and translator
Mannheim, Germany
May 1st, 2010*

Foreword

The publication of this book “Project Knowledge Management – Systematic Learning with the Project Comparison Technique” by Erwin v. Wasielewski fills me with a special joy. It is a translation of the author’s German book “Projektvergleichstechnik” which I edited in 2003 in the GPM Deutsche Gesellschaft für Projektmanagement e.V. series in Germany. I have closely watched the author’s work on Project Comparison Technique since his first publication in 1978, and I have always admired the analytical exactness of his investigations. Unfortunately, as I have to admit in retrospect, v. Wasielewski’s ideas were too far advanced. Maybe the fact that parametric analyses were rarely used in Germany also hindered the propagation of the method at the time.

During the 1970s and early 1980s, there was no talk about project characteristics, project benchmarking, or project evaluation. The only exception was an evaluation model presented by Bruce Baker in 1979 during the world congress in Garmisch-Partenkirchen, but this can hardly be compared to the approach in this book. Almost nobody reflected on evaluation of project experiences, although in the USA for several years cost data of completed projects were being used to get parametric estimation equations. A chapter “Project Close-out” did not yet exist, and even later was to be found only in advanced technical literature.

In recent years, this has changed dramatically. For example, the topics of the 2002 world congress of IPMA in Berlin included learning from projects and systematical application of experiences for new projects as well as benchmarking of projects and of project management systems. All of these items are now being discussed and new models being presented. In IT, project metrics and product metrics even are a special branch. Contrasting the results up to date with the “Project Comparison Technique” by v. Wasielewski, the latter stands out thanks to its striking originality.

I cannot but hope and wish that finally the ground may be prepared for this book also outside of Germany, and that learning from projects, in many organizations not more than a slogan, will be seriously implemented. This work offers a highly recommendable instrument to this end. I hope it will find many readers, stimulating research and development as well. I would be glad to hear some day that Roland

Gareis' words "Projects hardly learn" (in German: "Projekte lernen schlecht") is not true any more thanks to work like that by Erwin v. Wasielewski.

Oberau, January 2009

Heinz Schelle
Honorary President of the German Project Management Association
(GPM Deutsche Gesellschaft für Projektmanagement)

Acknowledgements

Looking back to past decades, I want to say thanks to the Agfa-Gevaert AG and my former boss, Dipl.-Ing. Fritz Knirr,

- for giving me the opportunity to try out new ways in evaluating and planning projects,
- and for later on letting me have data and documents from that time, which made it possible for me to go on developing the procedure.

Also I want to thank my former co-workers who collected the data together with me.

I want to thank Ass.d.L. Dipl.-Math. Lore Mair, Mannheim, who helped me with mathematical questions, looked over the manuscript of the German version and translated it into English.

Special thanks are going to Prof. Dr. Heinz Schelle, Universität der Bundeswehr, Munich, who, from the very beginning, has observed these investigations with benevolent interest, supported them with helpful discussions and edited the German version “Projektvergleichstechnik”.

I also want to thank Prof. Dr. Günther Altrogge, Universität Hamburg, and Prof. Dr. Jochen Schwarze, Universität Hannover, for giving various hints and tips during early stages of the development of this procedure.

Naturally, the present translation can't have the perfection of a native-speaker product. But, as a correct and up-to-date description of Project Comparison Technique so far requires rather a lot of special knowledge, Lore Mair and I trust that our readers will be so understanding as to oversee any linguistic or semantic errors that it may contain.

Munich, January 2009

Erwin v. Wasielewski

Contents

Part I Theory

1	Introduction	3
1.1	Content of this Publication	3
1.2	Reason and Purpose of Project Comparison Technique	4
1.3	Similarity of Projects	6
1.4	Relativity of Results	6
1.5	Methods of Computing	7
1.6	Initial and Final Data of Projects	9
1.7	Presentation of the Material	9
2	Breakdown of Project Objective	11
2.1	Basic Objective Structure	11
2.2	Expanded and Reduced Objective Structures	13
2.3	Goals	14
2.3.1	Freedom of Choice	14
2.3.2	Base-Goals and Check-Goals	15
2.4	Goal Weights	17
2.5	Forms and Values of Goals and Goal Weights	19
3	Partial Comparison	21
3.1	The Term “Partial Comparison”	21
3.2	Parameters	21
3.3	Targets and Influences	23
3.4	Scatter Value and Guide Value	24
3.5	Supplementing the Scatter Value	26
3.5.1	Sign Rule	26
3.5.2	Standardization of Variation	26
3.5.3	Scale Constant	28
3.6	Difficulty and Keeping	28
3.7	Additional Example for Partial Comparison	29
3.8	Including Several Parameters	30
3.9	Partial Comparison Without Parameters	31

- 4 Introduction to Terminology** 33
- 5 Total Comparison** 35
 - 5.1 Extending the Notions Difficulty and Keeping 35
 - 5.1.1 Within the Basic Objective Structure 35
 - 5.1.2 Within an Extended Objective Structure 37
 - 5.2 Goodness: Concept and Characteristics 38
 - 5.2.1 The Goodness Concept 38
 - 5.2.2 Within the Basic Objective Structure 39
 - 5.2.3 Within an Extended Objective Structure 41
 - 5.3 Classification of Terms 41
- 6 Comparison Typology** 43
 - 6.1 Types of Comparisons by Data Combinations 43
 - 6.2 Including Quasi-Parameters 44
 - 6.3 Descriptive and Inferential Comparisons 47
 - 6.4 Initial and Final Comparisons 47
 - 6.5 Comprehensive Terminology 51
- 7 Correction for Cost, Price, and Working-Time Index** 53
- 8 Mathematical Issues of Partial Comparisons** 55
 - 8.1 Balance Function 55
 - 8.2 Transformations 60
 - 8.3 Standard Deviation of Scatter Values 61
 - 8.4 Methodological Conditions and Steps of Parametric
Partial Comparisons 61
 - 8.5 Realization Probability of Project Objectives 64
 - 8.6 Parametric Project Model 67
 - 8.7 Difficulty as a Quasi-Parameter 69
 - 8.8 The Systematics of Terminology 70

Part II Application

- 9 177 Projects as an Example** 75
 - 9.1 Contents and Settings 75
 - 9.2 Product Range 76
 - 9.3 Project Realization and Organization 76
 - 9.3.1 Phases 76
 - 9.3.2 Project Features 78
 - 9.3.3 Project Management 79

- 10 Collecting, Keeping, and Processing Data** 81
 - 10.1 Origin 81
 - 10.2 The Concept of Collected Variables 82
 - 10.2.1 Overview 82
 - 10.2.2 Details 83
 - 10.3 Collection Stages and Reference Lists 85
 - 10.4 File Structure and Evaluation Tools 90
 - 10.5 Data Errors 92

- 11 Total Comparison of all 177 Projects** 95
 - 11.1 Purpose 95
 - 11.2 Goals and Goal Weights 95
 - 11.3 Parameters 97
 - 11.4 Balance Functions and Result Plots 98
 - 11.5 Statistics Issues 104

Part III Utilization

- 12 Presenting Comparison Results** 109
 - 12.1 General Considerations 109
 - 12.2 Comparison Tables 109
 - 12.3 Star Charts 112
 - 12.4 Planning Charts 114
 - 12.5 Time Series and Trend Charts 116

- 13 Application Issues** 125
 - 13.1 Getting the Parameters 125
 - 13.1.1 How to Search for Parameters 125
 - 13.1.2 How to Select Parameters 126
 - 13.2 Effects of Individual Parameters 127
 - 13.3 Stability of Project Goodness 130
 - 13.4 Organizing and Communicating Your Work 131
 - 13.5 Exogenous Planning and Controlling of Project Progress 132
 - 13.5.1 Purpose 132
 - 13.5.2 Data Base 132
 - 13.5.3 Application 133
 - 13.6 Objective-Independent Terminology 134

- 14 Specialized Prognosis Methods for some Base-Goals** 137
 - 14.1 Notions 137
 - 14.2 Price 137
 - 14.3 COCOMO 138
 - 14.4 Function Points 140
 - 14.4.1 Short Description 140

- 14.4.2 Inverse Calculation 141
- 14.4.3 Supplementing Inverse Calculation by Normal
Calculation 143
- 15 A Software Tool for Simple Project Comparisons 145**
- 16 Approaching Success Characteristics 147**
 - 16.1 Binary Objectives and Quasi-Objectives 147
 - 16.2 Taking Account of Binarity 148
 - 16.3 Taking Account of Stakeholder Satisfaction 150
 - 16.4 Taking Account of the Form of Project Management 152
 - 16.5 Taking Account of the Project Consequences 152
 - 16.6 Total Comparison, Including the New Criteria 154
- Table of Abbreviations 157**
- Bibliography of the German Edition 161**
- Additional Bibliography of the English Edition 165**
- List of Figures 167**
- Index 171**
- Author 175**

Part I

Theory

Chapter 1

Introduction

1.1 Content of this Publication

Project Comparison Technique means systematic calculations with empirical data from completed projects. Project Comparison Technique is part of knowledge management in project business and is used until now in three areas: long-time-trends, benchmarking and prognosis on similar projects.

Comparisons are made in all these cases: with benchmarking and long-time-trends, between completed projects or project phases; with prognosis, between completed ones and new ones. In all cases similar procedures and algorithms are used.

The results of these comparisons constitute a source of objective knowledge on projects, thus giving a foundation for other elements of project knowledge management. Project Comparison Technique is the indispensable project knowledge management tool to develop past data into know-how in a transparent way. Besides, even used on its own, this method shows the benefit of continuous systematic learning from projects, far beyond the rentability issue.

Project business until now has but few publications concerning Project Comparison Technique, covering only parts of the field. There are some major works on doing prognosis, especially in information technology, i.e. estimation of cost, schedule, and effort in IT projects. However, these volumes are very specialized, also in terminology, and do not cover the whole of Project Comparison Technique.

Therefore, the aim of the present publication is to cover the field in a general and fundamental way and to describe important features in a terminology and manner suited to all kinds of projects. The benchmarks are characteristics of project difficulty and project goodness that are valid throughout the industry, as well as enhanced project controlling methods.

As an example for project comparisons, we will use product development processes from a precision engineering manufacturer with a wide spectrum of production (Agfa-Gevaert AG, Fototechnisches Werk Munich). Basic ideas of the Comparison Technique have been published in 1978 and 1979 [88, 89], preliminary stages of the present terminology have been used in more recent publications [90, 92, 93]. But it took three decades to elaborate the present comprehensive systematics from the tentative beginnings and to complete the English terminology.

So now we have a new and consistent principle of prognosis and benchmarking for project realization, applicable for all projects where there exists information of similar projects in the past. Its use proves extremely fruitful and exceeds all known applications.

For the first time in the history of project management we show that and how goodness of project realizations can be evaluated objectively and numerically in detail and as a whole. In this publication, we will explain the first comprehensive, scientifically founded characteristics system for projects, formulate the first mathematical project model, demonstrate the usefulness of the characteristics system with authentic projects, and show the handling of the new tools and their presentation in tables and diagrams, amongst other things.

This work is a textbook on comparative project prognoses, project theory, project evaluation, and project benchmarking, not on project knowledge management as a whole or on project management. Nevertheless, it will also be useful in these other areas. It has the purpose to facilitate the first steps towards project comparisons for project management experts, to detail possible ways of approach and to relate experiences. Readers are supposed to have some knowledge about project management; mathematical and statistical aspects will be explained.

Parts of former publications have been incorporated into this work, resulting in a more stringent presentation. Thus, readers need not use these former publications for cross-reference, avoiding the nuisance of struggling with partially modified German terminology.

This book wants to address scientists and practitioners:

Scientists doing research work on project theory, project measurement, project evaluation, project characteristics or project characteristics systems, project knowledge management, or on similar fields, or depending on parts of these fields for other investigations. The carefully constructed mathematical definitions, explanations, and interrelations opening up fascinating new opportunities for understanding and further investigation are meant for this group of persons.

The group of practitioners comprises many industry academics who have to find watertight evaluations, characteristics, and prognoses of project realizations and are not afraid of mathematical formulae or calculations, being able to deal with them. These practitioners accustomed to theory are working in large (and growing) numbers in multi-project management and quality management of big and medium companies and other institutions, but also in management consulting.

1.2 Reason and Purpose of Project Comparison Technique

Data of completed projects contains valuable experiences. Project Comparison Technique makes use of these experiences, structures the way to do that and supports learning from past projects.

Strictly speaking, comparing projects isn't completely new. Planning a project, the expert will look at data from similar projects in the past – if he hasn't filed them in his memory already – and estimate the data for the new project accordingly.

Project Comparison Technique will put this subjective way of comparing projects onto an objective basis and extend it to get a prognosis of how the project will run.

Even more valuable than this support of planning a project are the characteristics that result from empirical data. With these characteristics, we can quantify the operative effects of project management instruments and actions, based on the project result. This is of eminent importance for the development of project management itself, as without this quantitative proof we have to rely on good faith and hypotheses only.

As an illustration, let us take an example given by de Wit [102] several years ago. De Wit describes that North Sea oil projects realized in the early 1970s suffered from excess costs of two or even three times the planned costs and excess duration of two to three years. Taking these facts into account, subsequent projects were planned with higher construction and project management costs, resulting in better attainment of time and cost objectives. Nevertheless, a controversial issue was whether improving the objective attainment really balanced increasing the project costs, because the judges were lacking objective evaluation standards.

In addition, de Wit observes that a project manager – deservedly – will be praised if the required performance is accomplished within the planned duration and cost limits. But, contrary to reality, apparently it doesn't matter whether the original schedule or planned costs were tight or generous. The evaluation standard applied is incomplete.

Hence, de Wit postulates to create precise efficiency criteria for projects in order to take efficiency into account when evaluating projects.

This necessary step can only be achieved by comparing projects. Comparison alone can round off project evaluation in a manner suited for management needs.

Of course, for any single project, its contract is binding. This, however, gives little information about its realization. We only start to learn systematically by comparing projects and reviewing their realization – for example, how difficult was the task, what time was needed, what were the costs, as with the North Sea oil projects mentioned – and by submitting the comparison results to an objective evaluation standard.

Speaking with de Wit, we have to create and use efficiency criteria. The characteristics of Project Comparison Technique solve exactly this evaluation problem and, moreover, supply a complete evaluation of the running of a project.

The well-known and widely accepted Project Management Award [30] – now Project Excellence Award – also is a tool for judging project running. It is a wide-range assessment process for outstanding projects, based on a special organization, but also on inevitably subjective components. Objective characteristics are playing only a minor role in this process. Its main value lies in intuitively acknowledging various factors, also of irregular or “soft” nature, as well as other circumstances of the project.

Project Comparison Technique on the other hand, being more specific, is a day-to-day tool to be used regularly by every company and every project executing organization to evaluate their projects on their own without calling on an outsider [94]. Purposes of Project Comparison Technique are:

- a) to extend the efforts of project business, so far directed mainly towards process design and process planning, by observing and checking their effects on project results.
- b) to prove, localize and systemize learning in project management in order to make projects faster, cheaper and better.
- c) to extend the basis for evaluation to more than a single observer's experience; to make possible comparisons between many projects, over long periods and different industries.
- d) to recognize dimension and realization probability of project objectives as early warning indicators to avoid planning errors and to optimize overall settings.
- e) to open up new sources of insight for project management.

1.3 Similarity of Projects

When we want to compare projects, we are supposing that there are similar projects to be compared. In this context, similar means that the projects concerned all possess essential features in which they are differing only quantitatively from each other.

As an example, we might take consecutive developments of products of similar magnitude and complexity in a company under the same organizational conditions, like those that will be used in the present documentation. Furthermore, it is possible to find similar projects in different companies, too, e.g. in construction or information technology.

Apart from these, other project types are likely to show similar projects. Unique projects actually are rare.

Nevertheless, large quantitative differences between projects can induce qualitative differences, too, if they lead to different handling of the projects. For some purposes we can restrict similarity requirements to the specific project qualities concerned [87].

That a certain resemblance is necessary does not contradict DIN norm 69901 [83] where uniqueness of conditions is defined as a project criterion. In the present work, e.g., uniqueness of the projects is given in the specific combination of product qualities and relevant market situation, whereas similarity lies in the technical, organizational and personnel way of handling the project.

1.4 Relativity of Results

Whenever we are investigating empirical data of projects, i.e. comparing these projects, the number of projects we are using is limited. It may be huge, there could be as many as hundreds, even thousands, of projects, but investigation results are valid for these projects only; furthermore, they will be outdated later on because of continuous changes in the object, technical, and organizational aspects of projects.

Nevertheless, we can define general characteristics that, in theory, are valid for any set and type of projects similar to each other, even for unique projects. Yet

any values obtained from these characteristics should be applied only to the set of projects used. For unique projects, we even cannot calculate these values, for lack of empirical data from similar projects.

Thus, all our investigation results are relative and fixed in time. A certain project out of one set may get a different evaluation with respect to another set of projects. In order to draw correct conclusions we will have to know which other projects the first one has been compared with.

Furthermore, the investigation results are relative in another sense, too:

In the present work, we are dealing with the degree of difficulty and the goodness of projects. With respect to the degree of difficulty, we will introduce a new term and use it as a characteristic: the Difficulty S (from German “Schwere”) [93].

Projects, however, are complex [49]. Strictly speaking, we should take into account all the conditions and properties of the projects to be compared.

This is not possible because of the amount of work and measuring problems involved; we will have to concentrate our attention on some of the properties of project realization, even when measuring the degree of difficulty and the goodness. To get a comprehensive picture of the projects to be compared, in spite of this restriction, we will observe their object, their quality requirements, their costs, and their duration.

Applying Project Comparison Technique, the user will reconstruct these criteria using goals supplied by his own projects, usually adding parameters that are to be chosen and whose purpose we will discuss later. Goal weights will be attributed to the goals reflecting varying project conditions.

The whole of these figures results in the overall evaluation of a project, similar to final school marks resulting from various subjects, the criteria used for evaluating a given subject and weights for the subjects.

Although goals, goal weights, and existing parameters can be customized according to the situation, at most they will give an approximate, never a complete picture of the project realization. Therefore we have to know not only what other projects, but also what variables the evaluation is based on.

Thus the results are relative in two ways: concerning the projects compared as well as concerning the variables used. So we have to work with appropriate care when interpreting the results.

1.5 Methods of Computing

Projects can be evaluated using endogenous or exogenous methods. Endogenous methods are based on data out of the project itself, exogenous methods mainly or totally on data of similar other projects.

Endogenous methods mainly yield control data, for example comparing planned against actual data [93], analyzing schedule trends and cost trends during the running of a project [29], calculating “Plantreue” (i.e., the degree of continuous matching of planned and actual values) [91] and calculating the degree of completion [29].

Endogenous methods do not rely on the existence of similar projects and are precise if the planned data are unambiguous; they can be applied only after having terminated the project phases concerned, and they do not involve statements on the degree of difficulty of the project objective [49, 93].

Endogenous methods are essential because projects have to be suitable for contracting, calculable and controllable. Project controlling [29] generally works with endogenous methods.

Exogenous methods mainly yield basic data – e.g., effort or duration – that can be used for dimensioning the project and as a reference point for endogenous methods. Examples of exogenous basic data are guide values for performances, e.g., excavation volume in construction, mounting performance in industry, programming performance in information technology. Another example is parametric cost estimations [28], which we will discuss later.

Exogenous methods rely on the accessibility of data from similar projects and are not really precise, but they can be applied in advance and show the degree of difficulty of the project objective. Exogenous methods are knowledge management [46, 59].

Exogenous methods are important because they let you see how difficult it is or was to achieve the project objective. The tighter the schedule and budget and the higher the technical and quality requirements, the more difficult they are to be realized. This is why Project Comparison Technique works with exogenous method mostly.

To get a thorough project evaluation, however, endogenous characteristics will be taken into account also in Project Comparison Technique, as well as exogenous methods can be used to improve the controlling of current projects. The present work will show appropriate methods for both of these cases.

Whatever the aims in using exogenous methods, we can use the parametric and several non-parametric ways of calculating.

Parametric means that the values of variables we are interested in will be derived from the values of other variables, the so-called parameters. Usually this will be achieved by using regression analysis [38, 42]. The parametric approach is the most important Project Comparison Technique method.

Non-parametric methods used in the present work are calculations of

- (arithmetic) means,
- weighted means from intermediate results,
- percentages and per mill values,
- standard deviations,
- quantiles (a statistical expression for measuring position).

Explanations for these methods that are to be used for exogenous calculations have been included throughout the appropriate chapters, reflecting project oriented guidelines. The present publication does not claim to give an exhaustive overview for all calculation methods suitable for comparing projects.

The project characteristics Difficulty and Goodness are valid in parametric as well as non-parametric methods.

Apart from the approaches mentioned, there are many expert techniques for how to make use of project experience inside one area or one type of projects. As far as I know, they consist of fixed evaluation formulae or of estimation tables, together with instructions for use that may contain calculations but without using project comparisons directly. An example will be shown in Sect. 14.3.

Although they nearly always are created from comparisons and so could be taken as side issues of or issues related to Project Comparison Technique, these expert techniques won't be treated in the present work, with the exception of the one mentioned above. This is necessary in order to keep this publication from growing out of bounds.

Anyway, these expert techniques are not themselves project comparisons, but rigid and refined results out of former comparisons at most. Similar to any single project comparison, once it is finished, its validity is limited and will become outdated as time passes. This also is a reason why we will concentrate our work on how to compare projects.

1.6 Initial and Final Data of Projects

Project data consists of lots of different variables that can be found mainly in two forms: initial values and final values.

Starting a project, we have objectives, conditions, ideas; they can be expressed by planned or nominal values that are to be achieved and that can change during the process. At the end of a project there are measurable results and actual values for most of the characteristics that had been represented by planned data in the beginning.

Some of the variables that will be used for our comparisons, however, do not lead to planned, nominal, or actual values; either they cannot be planned, or they are as uncertain at the end of the project as they were at the beginning. Examples are estimations of monetary value, of marketing possibilities or of reclamation rates. It might be confusing to call these numbers planned values or actual values.

That is why, in this work, we will be talking mostly about initial values and final values. Usually, but not always, initial values are planned or nominal values, whereas final values are actual values mostly. Only in special cases we will use the terms planned data, nominal data or actual data. Later on, we will define more exactly how initial and final values are assigned to the project process.

1.7 Presentation of the Material

The material will be treated in three parts, without a strict separation between them:

Part I is independent of any economical branch and consists of Chaps. 1 through 8. It deals with the basics of comparing projects, founded on project theory and

mathematics. Here, the main terms will be defined and the fundamental procedure will be thoroughly explained.

Chapter 8, dealing with mathematical-statistical issues, is directed towards readers who might want to handle parametric project comparisons themselves. It is meant to bridge the gap between project- and statistics-oriented theories originating from statistical literature. Other readers can skip the mathematical terms with only slight effects on the understanding of some evaluations.

Part II, containing Chaps. 9 through 11, will describe 177 authentic projects, demonstrating preparations and practice of project comparisons. The projects will be detailed including circumstances, data collection, and intermediate results, enabling the reader to understand further evaluations.

Naturally, this part reflects branch and enterprise particularities, but it has been conceived with care so that any readers from a different branch might understand and use it as well. Description of specific background is supposed to allow readers to see the evaluations in Part III not only as a result, but also as an example for project management development in an enterprise.

In Part III, which again shows a general approach, Chaps. 12–15 mainly deal with presentation and application of project comparisons. The evaluations mentioned in Part II will partially be used for illustration purposes, but stress will be laid on general use of project comparisons. Section 13.5 and Chap. 16 will introduce advanced methods using special assumptions, therefore only being dealt with at that point.

Wherever an illustration is inserted in the text, it will be called a “figure” for reasons of continuity, even if its content is a table. “To measure” may have the meaning of “to observe”, as opposed to “estimate” or “suppose”. References to the Bibliography will continue to be put in brackets.

Often project comparisons will be called comparisons for short.

It is safe to assume that trying to represent a new issue may bring about omissions or errors, which lie entirely in my responsibility. In these cases, I hope for the reader’s understanding.

Moreover, the translation by a German expert can’t have the perfection of a native-speaker product. But a correct and up-to-date description of Project Comparison Technique so far requires rather a lot of special knowledge that is not yet common [101, 103, 104].

Therefore, the special terms agreed upon by author and translator are suggestions to be discussed and improved, where appropriate. We hope to find understanding with our readers who are asked to overlook any clumsiness or linguistic error in the English version.

Chapter 2

Breakdown of Project Objective

2.1 Basic Objective Structure

Any project objective usually is composed of various subobjectives that can have different and varying weights. In order to subject a project as a whole to a comparison, its objectives have to be structured in a clear and consistent way, independent of the work breakdown structure [29].

Figure 2.1 shows a basic and very simple objective structure that we want to call the Basic Objective Structure, in distinction to other objective structures.

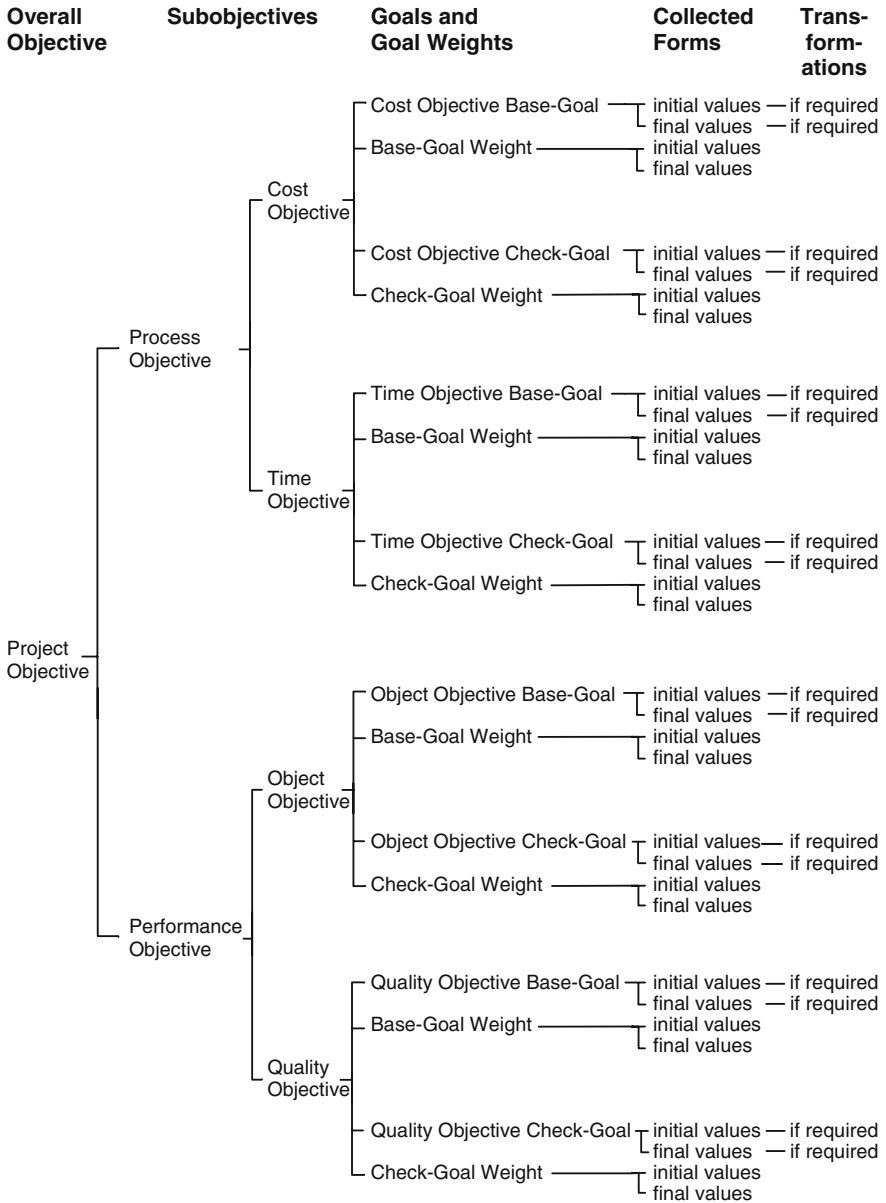


Fig. 2.1 Basic ObjectiveStructure

The Basic Objective Structure starts from the DIN (Deutsches Institut für Normung, German Standardizing Institute) definition for a project objective as “result to be achieved and realization conditions of the overall project task” [84]. In a first step, this project objective is being subdivided according to Fig. 2.2.

Combining low-level subobjectives, we get the respective high-level (sub)objectives. These three highest levels of the Basic Objective Structure can be applied to many types of projects; so evaluations can be made between projects from different branches.

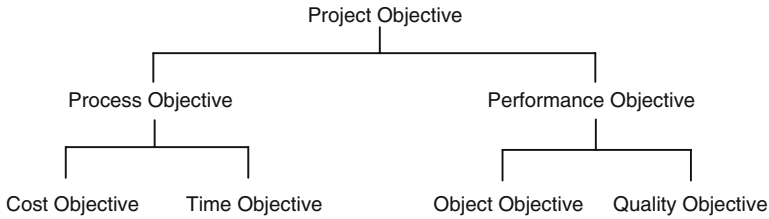


Fig. 2.2 Overall objective and subobjectives

2.2 Expanded and Reduced Objective Structures

More levels, as a whole or in parts, can be added to the structure shown in Fig. 2.2, if necessary. Figure 2.3 shows an example of an expansion with parts of a level.

Naturally, added levels will be designed according to the needs of a specific user and thus be less portable to other types of projects. Apart from a greater amount of work, there are no disadvantages connected with an expansion; on the contrary, it leads to a better founded project evaluation later on.

Significant names may be given to all added subobjectives. Breakdown into goals and goal weights will take place in the same way as with the Basic Objective Structure.

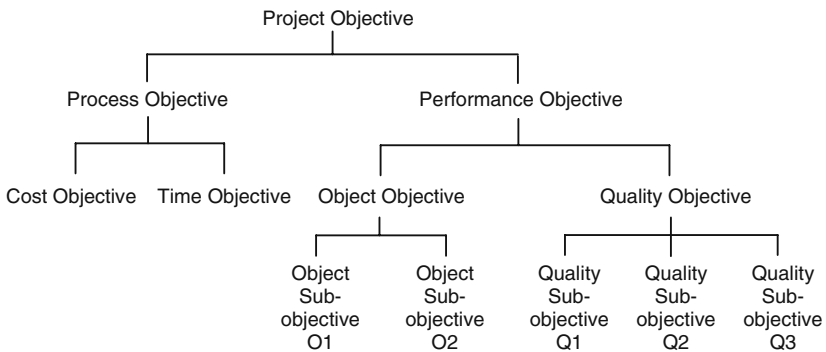


Fig. 2.3 Example of an expanded objective structure

On the other hand, the objective structure can be reduced, too. With information technology projects, for example, in an early stage only the amount of person-hours or person-months will be taken into account instead of separately comparing cost objective and time objective. Time and person requirements can then be derived using prior experiences, and costs will be calculated according to hourly wage rates.

As we have seen, the Basic Objective Structure is not a condition to be fulfilled, but only a generally useful structure model for project comparisons. We will consistently be using the Basic Objective Structure for our examples in the present work.

2.3 Goals

2.3.1 *Freedom of Choice*

Every lowest-level subobjective in any branch of the objective structure will be subdivided further into two goals: Base-Goal and Check-Goal. The reason for choosing exactly two will be treated in the next section; first, we want to look at goals in a general sense.

Goals are criteria that can be observed in any specific project, i.e. they are given in the project definition or in plans, calculations, reports etc., describing the respective subobjective. Their values, varying between projects, reflect details of process and performance that may be compared.

Possible goals could be with

- | | |
|---------------------|---|
| Cost objectives: | development costs, tool costs, assembly costs, total costs of the project, life cycle costs, costs for specific project phases or key activities, the effort in person-months already mentioned, excess building costs or project costs, etc. |
| Time objectives: | development duration, phase duration, project duration, periods between milestones, key activity duration, delay of acceptance deadlines, delivery delay, discrepancy between planned and actual repair times, etc. |
| Object objectives: | economic efficiency of the object after completion (e.g., operating costs for singular products, production costs for series production), maintenance effort, insurance effort, evaluation marks by independent testing institutions, future demolition costs or waste management costs, etc. |
| Quality objectives: | reliability, life span, rate of waste and rectification, rejections, excess warranty costs, rate of reclamations, downtimes, etc. |

This mixed bunch of goals shows how different possible project comparisons can be. Object objectives and quality objectives often merge; this does not interfere with project comparisons as the user can decide on the classification. Suitable to serve as a goal is any attribute that

- is to be maximized or minimized in the course of the project,
- can be observed in all projects to be compared and can be expressed on a scale, and
- whose importance justifies the introduction as a subobjective.

Generally, this freedom of choice concerning goals will inhibit the transfer of a specific set of goals to other types of projects. On the other hand, this freedom makes it possible for the user to customize the comparison.

To get an overall project evaluation, goals for all four objectives (cost, time, object, quality) should be taken into account, because any project is an inseparable compound of issues concerning cost, time, and performance. Only maximum completeness of criteria for the projects to be compared will lead to a reliable overall evaluation.

An unbalanced evaluation not only will be misleading, but also have negative impact on the projects: Probably the project team members will attend with special care to the attributes chosen for evaluation, which might affect the ones not chosen.

2.3.2 Base-Goals and Check-Goals

In the preceding section, we mentioned subdividing every lowest-level subobjective into two goals. This kind of decomposition reflects the typical double requirement inherent in the running of a project.

For example, given a specific performance, on one hand the project finish date should not be exceeded, on the other hand the planned project duration should be as short as possible. However, the shorter the planned project duration, the more difficult to keep the finish date and thus the time objective.

Likewise, with a given performance, on one hand the planned project costs should not be exceeded, on the other hand they should be low. The lower the planned project costs, however, the more difficult their keeping and thus the cost objective.

Similar requirements, though not always that obvious, arise for other subobjectives. Therefore, both sides of the double requirement always have to be observed.

To help the reader understand this issue better, a short example for a time objective is about to follow. Simultaneous observation of the respective cost objective will be cut out for the sake of more clearness.

Let us imagine that two project managers A and B, not knowing about each other, might independently be given the same performance objective (performance objective meant in the sense of Figs. 2.1 and 2.2). Project manager A demands 10 months' time to achieve his performance objective, project manager B demands 12 months. Both get identical tasks, observing these different conditions.

Later on, we might check the results: Project manager A took 11 months to achieve the performance objective, whereas B took 12 months and one week. Project manager A had set for himself a more difficult task than project manager B, but he

achieved his aim less accurately than B; nevertheless, A had been the faster one. Which one has shown better time handling?

Presenting different people with this question, probably we will get different answers. Maybe, we ourselves are not immediately sure about which result is to be held the better one.

A systematic way to answer our question opens up with the insight that any time objective consists of two different goals, i.e. the double requirement mentioned above. Looking separately at the goals “time needed” and “discrepancy to time agreed”, we can simplify our reasoning.

This reasoning cannot end up simply in a discrepancy/time ratio; this ratio would only be another discrepancy value, as here the actual time needed would not be visible any more. Rather, we have to think about our interest in the time needed and in the discrepancy in time.

At this point, we want to leave our example for the time being to make a transfer of our insight, attained for the time objective, to the other subobjectives. So, in order to get a well-founded project evaluation, we have to find goals to model the double requirement, which exists for every subobjective. Thus for every lowest-level subobjective we have to choose a Base-Goal and a Check-Goal in such a way that

- Base-Goal values (the time needed in our example) show how difficult it is or was to attain the subobjective,
- Check-Goal values (the time discrepancy in our example) show how well the Base-Goal values are or were kept (Fig. 2.4).

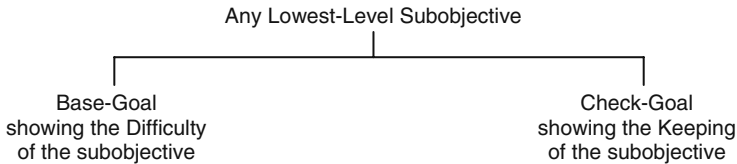


Fig. 2.4 Symbolic decomposition of lowest-level subobjectives

Usually the terms Difficulty and Keeping can be easily joined to the designations of the subobjective, e.g. Cost Difficulty and Cost Keeping. Cost Difficulty means “Difficulty of the cost objective”, Cost Keeping means “Keeping of the cost objective”. The same holds for other subobjectives. In this text, we will use capital letters wherever this special meaning of the words “keeping” and “difficulty” is needed.

Figure 2.5 shows an example. Keeping here is being represented by the discrepancy between final and initial values.

Instead of the discrepancy between final and initial values, other endogenous goals could serve as Check-Goals, e.g., the characteristics “Terminstreue” and “Kostentreue” (degree of continuous adherence to schedule and budget, respectively) [91] or corresponding actual/planned value ratios.

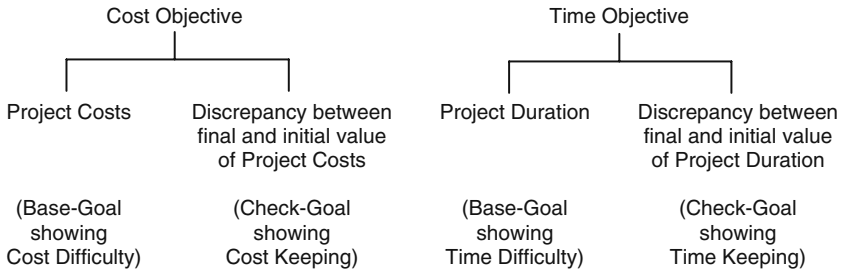


Fig. 2.5 Realistic decomposition of lowest-level subobjectives, shown by cost objective and time objective

The term “Difficulty” describes only part of the degree of difficulty of a project, i.e., the one represented by goals. Other aspects of the degree of difficulty can be taken into account differently, as we will see later on. Moreover, the terms Difficulty and Keeping will also be defined mathematically and become important characteristics.

Pairing off Base-Goals and Check-Goals not only serves to complete and systemize project evaluation, but again to neutralize inevitable impact of the evaluation on other projects. Any incomplete evaluation may interfere with subsequent projects.

For example, considering only the keeping of the time objective would favor making allowances for excess time in the plans and thus increase the planned duration. Evaluating duration only, on the other hand, might endanger the keeping of subsequent time objectives.

2.4 Goal Weights

Comparing projects, we also have to take into account the weight individual goals are bearing for a specific project. With some projects, it is most important to complete the project rapidly, with others to exactly keep the planned finish date, the budget, the object quality, or any other goal.

This varying importance of goals can be implemented into project comparisons by choosing goal weights. To every goal, a corresponding goal weight will be attributed.

In this way, every lowest-level subobjective now consists of four elements: one pair of goals and the corresponding pair of goal weights. Figure 2.6 shows this

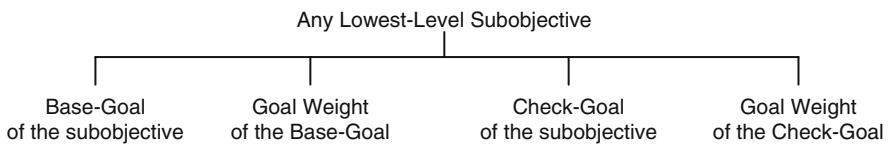


Fig. 2.6 Goals and goal weights of lowest-level subobjectives

expansion on Fig. 2.4. Weighting the goals naturally results in weighting all the lowest-level subobjectives relatively to each other.

You may wonder why we have separate goal weights for Difficulty and Keeping, respectively, of the same subobjective. The following time objective examples may help to understand this:

It could take ten years to develop a new medicament. Readiness for marketing should be reached as soon as possible (i.e., high goal weight of Time Difficulty), but the exact day does not really matter, even if, quite understandably, a specific date will be planned (i.e., low goal weight of Time Keeping).

An Olympic Games realization also may be thought about for ten years before the event. Depending on the necessary investment volume, there may be ample time (i.e., low goal weight of Time Difficulty), but delaying the beginning of the event is nearly impossible to imagine (i.e., high goal weight of Time Keeping).

Figure 2.7 is showing the theoretical structure of these two examples. Simply attributing an overall weight to the time objective would fail to take into account the different project conditions, i.e. the double requirement for project realization. The same goes for all the other subobjectives of any project.

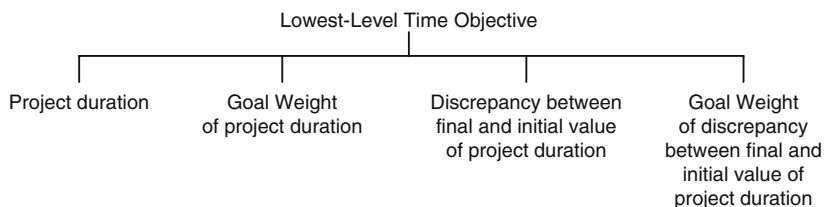


Fig. 2.7 Structure of a lowest-level time objective (example)

Now we can finally answer the question we mentioned in Sect. 2.3.2. There we wanted to know which one of the project managers A and B had shown better time management. The answer is “That depends on the goal weights”.

This is not an evasive response, but perfectly correct. Once we have indications as to the goal weights of our example there can be shown whose time management was the better one. We will explain how this can be calculated in Sect. 5.2, and we will extend the method to all goals.

Goal weights, on the other hand, not only help evaluate finished projects but also are strategic specifications for running the project. They should be documented in the project definition, although they can change during the process.

When defining the project objectives, weights of goals – or at least their ranking – will be discussed anyway, because knowing them is necessary for objective-oriented planning and managing of the project. Numeric indication of goal weights does not complicate matters, the more so as comparing projects during an early stage is particularly profitable.

The weight scale should be easy to handle; I would recommend integer values between 1 and around 20. During the test phase for introducing project comparisons, goal weights usually will have to be estimated retrospectively.

2.5 Forms and Values of Goals and Goal Weights

Every goal and every goal weight will appear in varying types or manifestations for the projects being compared, e.g. as an initial or planned value, as a final or actual value, or as an intermediate value. Later on, we will deal with mathematically transformed values as well as with values that have been corrected using inflation indices.

For the sake of shortness, we will call these different manifestations the “forms” of a goal or a goal weight. We will talk about the collected form, of index corrected and of transformed forms of a goal; generally, we will refer to goal forms, meaning the different well-defined goal manifestations.

In the same sense, we will talk about values as project values, as index corrected or transformed values of the goal etc. Project values are those that are observed directly on the project itself – or, coming from other sources, are equivalent to such observations – and that will be collected in an appropriate file for the use in project comparisons; for example, the collected forms of data consist of project values.

In this publication, we will assume only initial and final values. For project duration, e.g., we will call those two values initial project duration and final project duration, as well as for project costs, initial project costs and final project costs, respectively. Only for one non-parametric example (Sect. 13.5), we will make use of intermediate values for project comparisons.

Chapter 3

Partial Comparison

3.1 The Term “Partial Comparison”

For every goal, we do a separate project comparison, the Partial Comparison, thereby determining quantitative values for Difficulty and Keeping of this one goal.

The term “Partial Comparison” implies that one single goal only gives a limited or partial view of the projects concerned. Later on, we will calculate higher order characteristics out of weighted means of all Partial Comparisons and call this procedure Total Comparison.

For the time being, however, we will consider Partial Comparisons. Here, we will introduce an important feature: parameters.

3.2 Parameters

In project comparisons, parameters or project parameters are project properties that determine or, at least, influence goal values. Parameters describe volume and conditions of a project.

Doing a Partial Comparison, we use parameter values of projects that are similar to each other in order to deduce appropriate goal values. Thus, parameters rank among the basic elements of comparisons.

Examples for parameters are tunnel length for a tunneling project or the volume of functions in a data processing project. It is obvious that building a tunnel of 3 km length or writing a DP program which has to fulfill seven tasks will require more money and time than producing a similar tunnel of 800 m length or a program for only two of these functions.

This need not be detailed by planning work breakdown structure, process planning, work packages and activities [29]. In fact, with some experience in the field, the approximate interrelation between performance and costs or time needed is rather evident.

Other parameters could be

with product developments:	measurable product properties like weight or tonnage, size, material consumption, number of functions, number of parts, multi-language and/or decentralized development at different localizations, proportion of research, velocity or range for automotive and plane projects, number of items planned, etc.
with IT- and organizational projects:	number of code lines, commands or function points, programming language, extent of training, volume of documentation, number of people concerned, etc.
with structural engineering projects:	cubic meters of enclosed space, number of buildings, number of floors, floor space, equipment, kind of building, etc.
with road and tunnel building projects:	length by kilometers, extent of signaling equipment, extent of real estate purchase, project interruptions due to climate (freezing periods or tropical conditions), geological features, international cooperation, etc.

The parameters listed are examples only to illustrate the notion. Finding and choosing parameters will be treated in Sect. 13.1.

Without making a strict distinction, we can differentiate between natural parameters, describing the nature of the accomplishments to be performed in the project, and modal parameters, describing how the project has been or will be run. The above mentioned tunnel length, for example, would constitute a natural parameter, whereas the number of firms cooperating in building the tunnel would constitute a modal parameter. Further aspects of the degree of difficulty of a project that are not included in the Difficulty can be expressed by parameters, too.

Parameters also need a scale, at least a rough one. An important feature is causality in the parameter effects on the goals. Wild shots on series of numbers whose relationship is uncertain may lead to erroneous conclusions if the corresponding facts do not constitute cause and effect. An example might illustrate this:

Tourists visit attractive cities mainly in summer. Likewise, some road repair works are carried out preferably in summer. One might assume that roadwork attracts tourists. Tourists, however, will not stay away one summer when there happens to be no roadwork going on.

Only attentive care in choosing parameters can prevent similar errors that may even be less obvious.

As with goals and goal weights, for parameters, initial and final values will be collected, e.g. initial number of parts and final number of parts. These again are collected forms or project values of the parameters.

Later on, we will deal with other influences on the running of a project, apart from parameters: quasi-parameters, which will be called differently. Similarly to goals, parameters and quasi-parameters may have to be transformed mathematically before being used in a Partial Comparison.

3.3 Targets and Influences

In order to deduce goal values from parameter values, as mentioned at the beginning of the preceding section, we have to know the numeric relationship between goals and parameters. Hereby, we do not mean the causality postulated in the preceding section. This usually can be recognized only by expertise and experience and will be assumed to exist.

Rather, we want to introduce a formal relationship, allowing calculations and being as straightforward as possible. Generally, the real causality is too complicated for this aim, even if we were able to determine its numeric details.

Therefore, we use an assumption, a model. For the sake of clearness, we choose the simplest assumption: linear relationship between goals and parameters. This means that in a chart, for example, the assumed relationship between goal and parameter, apart from some scattering, will be visible as a straight line.

We will demonstrate that in the section to follow. Assuming a linear relationship also leads to good calculation possibilities.

In practice, however, goals and parameters often fail to show a linear relationship. Usually a so-called scatter plot of goals versus parameters, easily put on the screen of a DP unit, shows the points scattering around an imaginary curve.

In these cases, we can manage by transforming goals and parameters as mentioned before, see Chap. 8. It is safe to suppose that we will almost always be able to create a more or less linear relationship this way, and to verify it by way of scatter plots.

Transformation is not deformation of data. The true relationships between collected forms of goals and parameters almost never are known mathematically. Though the collected form, e.g. days, weeks, number of pieces, weights, amount of money etc., probably is the easiest to record, this does not give any priority to this form as far as constructing a model is concerned. We are seeking a simple relationship which can be widely used for our calculations.

Once the best, or, at least, a satisfying linear combination of goal form and parameter form, with or without transformations, is found, these will be called target and influence, respectively. The goal form chosen gives the target variable, and the parameter form chosen the influence variable. Quasi-parameters, too, can lead to influence variables.

The target and influence values we will call model values. Other forms of goal and parameter may possess linear relationships, too, but we do not know or need not make use of this fact.

Note: Although goal and target are similar notions, they must not be confused. A target is a chosen goal form that shows an approximately linear relationship to one or more chosen parameter form(s), the influence(s).

3.4 Scatter Value and Guide Value

Now we want to demonstrate the parametric calculation method, using an example.

Imagine four similar projects, whose durations and volumes we may have observed and registered, and whose aim may have been to develop a certain machine. The observed final values of project duration as measured in 5-day working weeks, and the observed final values of project volume as measured in number of parts the machine includes, may show an approximately linear relationship without transformation as shown in Fig. 3.1.

Project	Final project duration (working weeks)	Final number of machine parts
P ₁	20	90
P ₂	25	140
P ₃	30	150
P ₄	40	310

Fig. 3.1 Example for Partial Comparison

The approximate relationship between final project duration (target variable) and final number of parts (influence variable) in our example can be represented graphically by a best fit straight line according to Fig. 3.2. How such a straight line, which we want to call balance line, can be calculated we will treat in Chap. 8, too. In simple cases, such as Fig. 3.2, it would be possible to draw the balance line by hand.

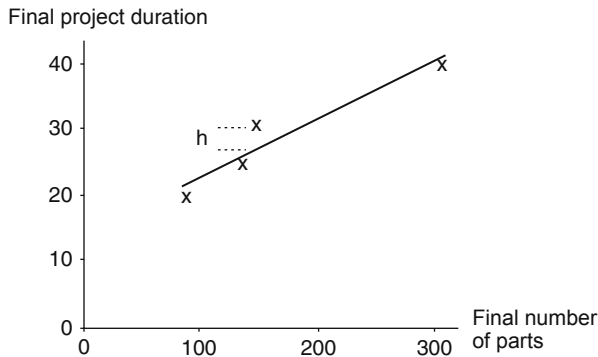


Fig. 3.2 Balance line between final project duration and final number of parts of the example

The horizontal axis (here: final number of parts) is called abscissa, the vertical axis (here: final project duration) is called ordinate. The difference in height h between an observed duration value and the point vertically above or below it on the balance line is the fundamental measure of our comparisons. As the project duration values are scattered around the straight line, h will be called scatter value.

We can calculate the scatter value, a procedure we will treat in Chap. 8, or, in a straightforward case, take a diagram such as Fig. 3.2 and measure the scatter value graphically, parallel to the ordinate, given in ordinate units. Points above the balance line have a positive scatter value, points below a negative one.

Figure 3.3 shows the calculated results as h , the graphically measured values together with a certain inexactness as h_g .

Project	Scatter value h calculated	Scatter value h_g measured
P ₁	- 1.60	- 1.5 ... - 2.0
P ₂	- 0.93	- 0.5 ... - 1.0
P ₃	3.20	3.0 ... 3.5
P ₄	- 0.66	- 0.5 ... - 1.0

Fig. 3.3 Project duration scatter values for the example

For Partial Comparisons, the reference point on the balance line will be taken as guide value for the project concerned. The definition of a scatter value reads thus as follows:

$$\text{Scatter value } h = \text{observed value} - \text{guide value}$$

This defining equation also is valid with any transformations of collected forms, different target or influence variables, as well as more sophisticated functions.

The scatter value h must not be taken with undue exactness. Error estimation can show the reason why:

Let us suppose that by recording project duration in whole weeks, up to 2.5 working days, i.e. 0.5 weeks, have been rounded up or down. Scatter values, being smaller than the project duration, are relatively more affected by this inexactness (Fig. 3.4). Further errors might be produced by difficulties in defining project duration or number of parts.

Project	Scatter value h calculated	Scatter value h_g measured
P ₁	- 1.60 ± 0.5	- 1.5 ... - 2.0 ± 0.5
P ₂	- 0.93 ± 0.5	- 0.5 ... - 1.0 ± 0.5
P ₃	3.20 ± 0.5	3.0 ... 3.5 ± 0.5
P ₄	- 0.66 ± 0.5	- 0.5 ... - 1.0 ± 0.5

Fig. 3.4 Error estimation for Fig. 3.3

Figure 3.4 shows that in the case we assumed, the calculated solution uncertainty reaches the measured solution inexactness and, with project P₄, almost the amount of the scatter value itself. In reality, the calculation, whose details we will explain

later, may be seemingly exact, but often it must not be taken as more certain than the graphical solution with a best fit line (balance line) that has been drawn by hand among the points.

We have to be aware of this inherent uncertainty of scatter values, especially small ones. But in spite of this uncertainty, the parametric method by taking into account parameters usually gives more significant scatter values than a non-parametric method.

3.5 Supplementing the Scatter Value

3.5.1 Sign Rule

Some readers may have noticed that according to the equation defining the scatter value, project durations above the guide value will have a positive scatter value, whereas those below the guide value will have a negative one. As we want to evaluate projects by their scatter values, first we want to adapt its sign to our common understanding of projects, insofar as not large project durations but rather small ones are understood to be “positive”, i.e. desired results.

Here we have to pay attention to the fact that goals have to be either maximized or minimized in a project. With goals that, like project duration, are to be minimized, negative scatter values are desired, but with those that are to be maximized, e.g. “Termintreue” (i.e., the degree of continuous matching of planned and actual time values), negative scatter values are undesirable.

Thus, for goals to be minimized, we may multiply the scatter value h by the factor -1 or reverse the underlying subtraction. Put in a general way, we form a new term h' out of the scatter value h that we want to call “sign-adjusted scatter value” or “adjusted scatter value”, for short:

For goals that are to be minimized:

$$\text{adjusted scatter value } h' = -h = \text{guide value} - \text{observed value}$$

For goals that are to be maximized:

$$\text{adjusted scatter value } h' = h = \text{observed value} - \text{guide value}$$

Later on, we will use the apostrophe (inverted comma) $'$ to denote modifications of other terms, too.

3.5.2 Standardization of Variation

As we have mentioned in Sect. 3.1, the results got by Partial Comparisons will be combined to construct higher order characteristics by calculating weighted means.

This calculation would be affected by scatter values of different goals having not only different dimension, e.g. time and monetary units, but perhaps also completely different magnitude of variation.

To illustrate this effect, let us assume that for the four projects of our example, in addition to the project duration, the project costs may have been registered. In our example, the differences between actual values and respective guide values for project costs show far less variation than those for project duration. For sake of simplicity, we will not use any goal weights.

Figure 3.5 shows additional assumed sign-adjusted scatter values and the rounded arithmetic means calculated from the respective adjusted scatter values. For the time being we want to neglect the discrepancy in kind between time respectively cost differences.

Project	Adj. scatter value h'_1 of final project duration	Adj. scatter value h'_2 of final project costs	Mean h'_M of h'_1 and h'_2
P ₁	1.60	0.38	0.99
P ₂	0.93	0.43	0.68
P ₃	-3.20	-0.98	-2.09
P ₄	0.66	0.17	0.42

Fig. 3.5 Values and means of sign-adjusted scatter values for project duration and project costs of the example

It is easy to see that the means h'_M in Fig. 3.5 are influenced mainly by h'_1 : If project P₃, for example, had a different h'_2 value of very good 0.44 instead of -0.98, which is the lowest one, even this would improve the mean only relatively little from -2.09 to -1.38. Even being the best project as far as one of the criteria – duration and costs – is concerned, P₃ would continue to show the worst mean.

In fact, these considerations are not completely strict, because changing the value for P₃ would equally change the project cost balance line and so the cost scatter values for all of the projects; we do not know for sure whether P₃ with its new value really would be the best project regarding costs. However, this is not essential to our thoughts.

So in such a mean, the target variable with greater variation will dominate the others. This is undesirable in the system of project comparison characteristics. Any dominance of a certain goal should not be determined by variations, but by the goal weights chosen.

For this reason, we now couple the sign-adjusted target scatter values h' with the corresponding variation, dividing them by their standard deviation.

The standard deviation is a common statistical measure for variation, whose calculation is provided not only by any statistical analysis program but also by several spreadsheet programs and pocket calculators. Simply speaking, in our case the standard deviation is some kind of average distance between observed values and balance line. This calculation also will be treated in Chap. 8.

So we convert the adjusted scatter values h' to relative adjusted scatter values h'/s , s being the standard deviation of the adjusted scatter values h' . As the standard deviation has the same dimension as the adjusted scatter values, e.g. working weeks, the relative adjusted scatter value h'/s is a nondimensional number, contrary to scatter value and adjusted scatter value.

The relative adjusted scatter values h'/s of different targets can be combined into higher order characteristics without the difference in variation between the values compared creating any problems, because the relative adjusted scatter values are standardized, i.e. relative with regard to this variation. In addition, different dimensions of scatter values and adjusted scatter values are neutralized.

3.5.3 Scale Constant

Finally, to polish off the scatter value, adding a scale constant is very convenient.

Thanks to the sign rule, the relative adjusted scatter value h'/s is positive whenever the difference to the guide value is in the potentially desirable direction, and negative when it is not. But often, having both positive and negative numbers may be irritating.

This can be avoided by adding a scale constant such that the Partial Comparison results always fall in the positive region. My own investigations have shown that the value 5 is appropriate for that purpose; the result 5 thus will characterize any project whose target value is situated exactly on the balance line. Values above are better, those below are worse than the guide value.

3.6 Difficulty and Keeping

For each one of the projects compared, the result of a Partial Comparison is the relative adjusted scatter value, increased by a scale constant. Mathematically, this reads

$$\frac{h'}{s} + 5 ,$$

h' being the adjusted scatter value and s the standard deviation of this scatter value.

Now we should take into account that this mathematical expression will have different meanings, depending on its origin being the scatter value of the target variable for a Base-Goal or for a Check-Goal, in short, a Base-Target or a Check-Target. With a Base-Target, it will designate the degree of difficulty of the project subobjective, with a Check-Target, the exactness of keeping this subobjective. Therefore, it conforms to the terms Difficulty and Keeping introduced in Sect. 2.3.2.

Thus we will call this term Difficulty whenever the corresponding Partial Comparison applies to a Base-Target, and we will call it Keeping when the comparison applies to a Check-Target:

$$\frac{h'}{s} + 5 = \begin{cases} \text{Difficulty S} & \text{with Base-Targets} \\ \text{Keeping E} & \text{with Check-Targets} \end{cases}$$

Difficulty S (from German “Schwere”) and Keeping E (from German ”Einhaltung”) of any subobjective can so be calculated from Partial Comparisons. Later on we will further extend these terms.

Figure 2.5 already has shown how to combine the terms Difficulty and Keeping with subobjective denotations. Similarly we want to characterize the symbols S and E with a letter for the respective target, e.g. S_K Cost Difficulty, E_K Cost Keeping, S_T Time Difficulty, etc.

Now we can continue our example of Figs. 3.1 to 3.5. Here, the standard deviations are (calculation will be demonstrated in Chap. 8):

$$s_{h'_1} = 2.66 \quad (\text{standard deviation of scatter values for final project duration})$$

and

$$s_{h'_2} = 0.81 \quad (\text{standard deviation of scatter values for final project costs})$$

Converting this to

$$S_T = \frac{h'_1}{2.66} + 5 \quad \text{and} \quad S_K = \frac{h'_2}{0.81} + 5, \quad \text{respectively,}$$

we get the numbers shown in Fig. 3.6. Finishing this calculation, we have worked out the first two of the basic characteristics of Partial Comparisons.

Project	Time Difficulty S_T	Cost Difficulty S_K
P_1	5.60	5.47
P_2	5.35	5.53
P_3	3.80	3.79
P_4	5.25	5.21

Fig. 3.6 Results of two Partial Comparisons for the example

Interpreting the values of Fig. 3.6, we have to allow for the possible error of the scatter value h , as we have shown for the project duration in Fig. 3.4. In Fig. 3.6, the small deviations from value 5 in project P_4 are concerned primarily.

3.7 Additional Example for Partial Comparison

Check-Goals usually are (endogenous) characteristics themselves, but as far as Partial Comparisons are concerned, they are treated the same as Base-Goals. This will

not lead to problems; on the contrary, it gives supplementary checking information, which is desirable.

Example: Let us suppose that a project has been finished, exceeding the initial project duration by four months. Certainly nobody will be pleased by this result.

If, however, we find that three similar projects consulted for comparison all were finished with even more excess duration of up to 10 months, then it becomes easier to accept the result. Comparing sheds new light on the original information.

As far as graphics are concerned, Check-Goals or rather their respective target variables can generally be treated like Base-Targets, too. Figure 3.7 illustrates the example treated above, again assuming linear relationship without transformations. The Keeping characteristic ranks the projects according to their differences to the guide value for excess project duration.

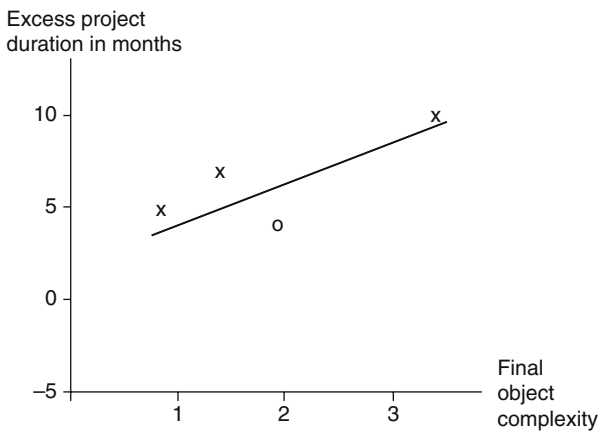


Fig. 3.7 Partial Comparison of a Check-Goal, here: excess project duration; o = example project

3.8 Including Several Parameters

We can include several parameters in the Partial Comparison for one target simultaneously. On entering a second influence, the model becomes a three-dimensional one, of a target and two influences. We could draw a perspective graph for these three dimensions, turning the balance line of Fig. 3.2 into a balance (best fit) plane.

For a quick and practical application like Fig. 3.2, however, this perspective drawing would be less suitable, needing more drawing effort, being less clear, and being more apt to convey wrong impressions. That is why, having more than one influence, we recommend switching to the purely numerical solution, accepting the resulting loss of visual information.

The different manifestations of numerical solutions will be subsumed in the term balance function. Once again, calculation details will all be treated in Chap. 8.

3.9 Partial Comparison Without Parameters

If none of the existing parameters can appropriately explain the variation of a certain goal, or if we want to compare only two projects, we go back to the arithmetic mean of the goal values for the comparison. This means using a non-parametric procedure instead of a parametric one.

Inverting the case that using two influences will expand the balance line into a balance plane, in the case of no known influence the balance line will be reduced to a single point. This point, the arithmetic mean, is the guide value for all projects of the Partial Comparison concerned, project and model being one here so that no transformations will be needed.

For an illustration, we want to look at the Sect. 3.7 example with four projects and their excess project durations. The excess may be

- P₁ 5
- P₂ 7
- P₃ 10
- P₄ 4

Now we want to suppose that either none of the parameters available can even approximately explain the excess or that we take an existing parametric explanation, as in Fig. 3.7, to be a pseudo-causality because of its contradicting prior knowledge. We need not, however, do without a Partial Comparison of excess project duration: now we will confine ourselves to the project value mean as a guide value.

The project value mean of “excess project duration” is

$$(5 + 7 + 10 + 4)/4 = 6.5$$

This mean takes the place of the balance line. Therefore, the guide value 6.5 is valid for all four projects, which carries the disadvantage of the scatter values being a lot greater than they would be using appropriate parameters; they even may change their signs. All the same, we need not abandon the Partial Comparison concerned.

Figure 3.8 shows the adjusted scatter values, i.e. the sign adjusted project deviations from this mean. The observed Check-Goal values are subtracted from the guide value 6.5 and so get the correct sign.

Project	Adjusted scatter values h' of excess project duration
P ₁	h' _{P₁} = 6.5 - 5 = 1.5
P ₂	h' _{P₂} = 6.5 - 7 = -0.5
P ₃	h' _{P₃} = 6.5 - 10 = -3.5
P ₄	h' _{P₄} = 6.5 - 4 = 2.5

Fig. 3.8 Calculating the adjusted scatter values for a Partial Comparison without parameters (example)

In Fig. 3.8, too, excess project durations having a positive adjusted scatter value h' are desired, those with a negative adjusted scatter value are undesired.

The standard deviation of the scatter values—whose calculation we treat in Sect. 8.3—for this example is

$$s \approx 2.6$$

which gives the following Keeping values:

$$E_1 = 1.5/2.6 + 5 \approx 5.6$$

$$E_2 = -0.5/2.6 + 5 \approx 4.8$$

$$E_3 = -3.5/2.6 + 5 \approx 3.7$$

$$E_4 = 2.5/2.6 + 5 \approx 6.0$$

Calculating a Difficulty would follow the same procedure if a Base-Goal instead of a Check-Goal were the basis of the Partial Comparison. Using the project comparison characteristics does not necessarily involve using parameters or the parametric procedure.

In spite of all this, a Partial Comparison without parameters is a makeshift solution and should not be applied except with Check-Goals or being short on projects. It only serves to avoid possible incompleteness of a Total Comparison or in order to compare two projects on their own.

Chapter 4

Introduction to Terminology

In previous chapters, we have already introduced several terms. In preparation of chapters to come, we want to compile these and some more terms. We have listed them in mathematical notation for explanations, and in a sometimes different, simpler notation for use in files and spreadsheet programs that will be called the “DP” (data processing) notation and will be used in several of the evaluations shown, for instance. Of course, you might want to customize both notations.

Projects are denoted by P and consecutive numbers i that mark the individual projects in a comparison. In Figs. 3.3, 3.4 and 3.5, for example, i had values 1 through 4. The number i only will be needed for explanations concerning the comparison; it doesn’t show in the files and evaluations later on.

In addition, for every project P we need a documentation number d to characterize its data on collecting and archiving. The projects labeled by i usually are selected out of the set of projects labeled by d .

When keeping and evaluating the data, not i , but d will be used to denote individual projects. To enhance the difference, we will show the numbers i with one or two digits as a subscript, but the numbers d always with three digits and not as a subscript.

Further numbers for subobjectives added for an expanded objective structure, e.g. in Fig. 2.3, also will not be printed as subscripts, because in the chapters to come, this would lead to an irritating lot of interwoven subscript lines.

We will continue to use symbols derived from German terminology throughout this translation, as they offer a conflict-free designation system and the chance for an international abbreviation standard for project comparisons. An equivalent set of English abbreviations would not be easy to prepare, and would not be appropriate before discussing the proposed terminology with native-speaker experts.

Project i or d , respectively (i = sequence in a Partial Comparison, e.g. P_1, P_2, P_3 , etc; d = chronological sequence of collection, e.g. P001, P002, P003, etc.)	Math. P_i	DP Pd
Scatter value of a project	h	h
Sign-adjusted scatter value	h'	h'
Standard deviation of scatter values of a Partial Comparison	s	StDev
U being any lowest-level subobjective, we have		
Difficulty of subobjective U	S_U	US
Keeping of subobjective U	E_U	UE

Note that combinations of symbols in DP notation, for instance US and UE, are not the mathematical product of the respective values multiplied, e.g. U times S, but always an indivisible notation for a single variable. To make this clear, we always will write a multiplication sign (\times) when multiplying variables in the next chapter.

Further abbreviations:

Base-Goal weight of subobjective U	Math. W_{S_U}	DP WUS
Check-Goal weight of subobjective U	W_{E_U}	WUE

You see that we will use the Difficulty and Keeping symbols for any subobjective to denote the respective goal weights. Thus we will be able to give the weights in a general way without specifying the corresponding Base-Goal or Check-Goal.

Whenever the objective decomposition of projects does not go beyond the Basic Objective Structure, lowest-level subobjectives are cost, time, object, and quality objective. In this case, the characteristics resulting from Partial Comparisons are

Difficulty of the cost objective (Cost Difficulty)	Math. S_K	DP KS
Keeping of the cost objective (Cost Keeping)	E_K	KE
Difficulty of the time objective (Time Difficulty)	S_T	TS
Keeping of the time objective (Time Keeping)	E_T	TE
Difficulty of the object objective (Object Difficulty)	S_O	OS
Keeping of the object objective (Object Keeping)	E_O	OE
Difficulty of the quality objective (Quality Difficulty)	S_Q	QS
Keeping of the quality objective (Quality Keeping)	E_Q	QE

In the course of our future explanations, we will use not only these symbols, but also the simplified terms given here in parentheses, like Cost Difficulty etc. Usually they are analogous to DP notation, with the exception of goal weights.

Chapter 5

Total Comparison

5.1 Extending the Notions Difficulty and Keeping

5.1.1 Within the Basic Objective Structure

Now we are going to talk about higher-level characteristics and thus about integrative evaluation of projects, i.e. Total Comparison. Total Comparison means summarizing Difficulty and Keeping from Partial Comparisons for all subobjectives, using weighted means, resulting in a system of characteristics that represents at least the Basic Objective Structure completely.

This calculation procedure is non-parametric and means adding the Partial Comparison results, similar to the single marks of a test certificate, to get an overall result. In Sect. 16.2, we will still further expand this notion of a Total Comparison.

All Partial Comparisons summarized have to relate to the same set of projects. The goal weights are used for weighting the characteristics when building the means.

First, the Basic Objective Structure (cf. Figs. 2.1 and 2.2). We can define the following weighted means:

$$\text{Process Difficulty} \quad S_A = \frac{S_K \times W_{S_K} + S_T \times W_{S_T}}{W_{S_K} + W_{S_T}}$$

$$\text{Process Keeping} \quad E_A = \frac{E_K \times W_{E_K} + E_T \times W_{E_T}}{W_{E_K} + W_{E_T}}$$

$$\text{Performance Difficulty} \quad S_L = \frac{S_O \times W_{S_O} + S_Q \times W_{S_Q}}{W_{S_O} + W_{S_Q}}$$

$$\text{Performance Keeping} \quad E_L = \frac{E_O \times W_{E_O} + E_Q \times W_{E_Q}}{W_{E_O} + W_{E_Q}}$$

$$\text{Project Difficulty} \quad S_P = \frac{S_K \times W_{S_K} + S_T \times W_{S_T} + S_O \times W_{S_O} + S_Q \times W_{S_Q}}{W_{S_K} + W_{S_T} + W_{S_O} + W_{S_Q}}$$

$$\text{Project Keeping} \quad E_P = \frac{E_K \times W_{E_K} + E_T \times W_{E_T} + E_O \times W_{E_O} + E_Q \times W_{E_Q}}{W_{E_K} + W_{E_T} + W_{E_O} + W_{E_Q}}$$

Now we can continue the list of symbols started in Chap. 4:

	Math.	DP
Difficulty of process objective (Process Difficulty)	S_A	AS
Keeping of process objective (Process Keeping)	E_A	AE
Difficulty of performance objective (Performance Difficulty)	S_L	LS
Keeping of performance objective (Performance Keeping)	E_L	LE
Difficulty of project objective (Project Difficulty)	S_P	PS
Keeping of project objective (Project Keeping)	E_P	PE

Now the notions of Difficulty and Keeping, so far only defined for Partial Comparison results, have been extended to weighted means similar to each other. Henceforward, Difficulty means one of the following:

1. the unweighted result of a Partial Comparison for a Base-Target,
2. the weighted mean of two or more such results for Base-Targets.

Similarly, Keeping will mean one of the following:

1. the unweighted result of a Partial Comparison for a Check-Target,
2. the weighted mean of two or more such results for Check-Targets.

All of these variables are expressed in the same units on the same scale, so the extension does not present any technical problems. There is no danger of mixing up unweighted results and weighted means because characteristics labeled “process”, “performance” and “project” always are weighted means, whereas all other characteristics in the Basic Objective Structure are unweighted results.

Figure 5.1 demonstrates the hierarchical structure of the Difficulty and Keeping characteristics in a sort of summary for the Basic Objective Structure. Underneath each characteristic, the corresponding mathematical notation is given in the left-hand corner, the DP notation in the right-hand corner.

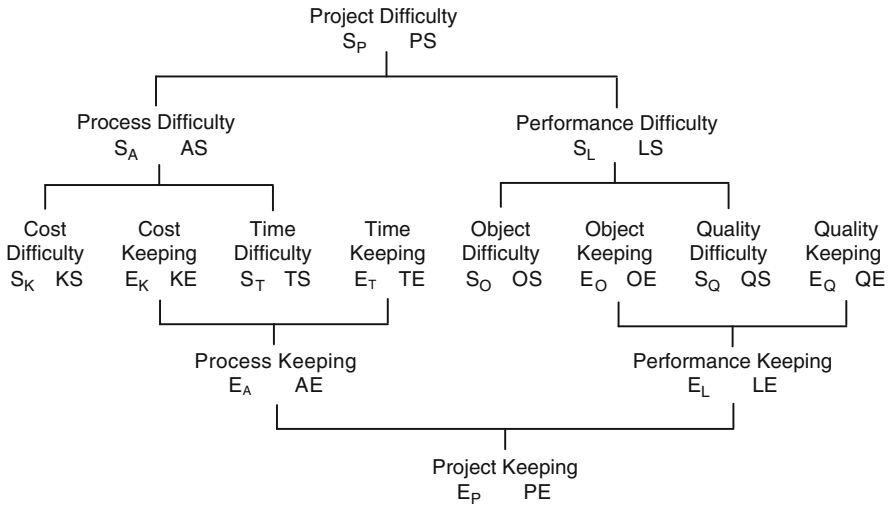


Fig. 5.1 Structure for Difficulty and Keeping for the Basic Objective Structure

5.1.2 Within an Extended Objective Structure

With an extended objective structure, several or all of the lowest-level subobjectives structurally are on a lower level than with the Basic Objective Structure, and the number of Partial Comparisons increases. This involves only minor changes in proceeding or notation; some of the basic characteristics that with the Basic Objective Structure were results from Partial Comparisons are now weighted means and as such require a special notation. We will use the grave accent (`) for this.

For example, the Difficulty of two object subobjectives O1 and O2 from Fig. 2.3, S_{O1} and S_{O2} , results in the Object Difficulty

$$\text{Object Difficulty } S_{O'} = \frac{S_{O1} \times W_{S_{O1}} + S_{O2} \times W_{S_{O2}}}{W_{S_{O1}} + W_{S_{O2}}}$$

With any actual extended objective structure, the object subobjectives will have their own significant names. Otherwise you can simply designate the characteristics by “Object Sub-Difficulty S_{O1} ” and “Object Sub-Difficulty S_{O2} ”, as we do here.

In the same way, the Difficulty of three quality subobjectives Q1, Q2, and Q3 from Fig. 2.3, S_{Q1} , S_{Q2} , and S_{Q3} , results in the Quality Difficulty

$$\text{Quality Difficulty } S_{Q'} = \frac{S_{Q1} \times W_{S_{Q1}} + S_{Q2} \times W_{S_{Q2}} + S_{Q3} \times W_{S_{Q3}}}{W_{S_{Q1}} + W_{S_{Q2}} + W_{S_{Q3}}}$$

As next higher component, the Performance Difficulty results in

$$S_L = \frac{S_{O1} \times W_{S_{O1}} + S_{O2} \times W_{S_{O2}} + S_{Q1} \times W_{S_{Q1}} + S_{Q2} \times W_{S_{Q2}} + S_{Q3} \times W_{S_{Q3}}}{W_{S_{O1}} + W_{S_{O2}} + W_{S_{Q1}} + W_{S_{Q2}} + W_{S_{Q3}}}$$

Object Keeping, Quality Keeping, and Performance Keeping can be calculated in the same way. As far as cost objective, time objective and process objective are concerned, there are no differences to the Basic Objective Structure.

In this example, the symbols have the following meaning:

	Math.	DP
Cost Difficulty	S_K	KS
Cost Keeping	E_K	KE
Time Difficulty	S_T	TS
Time Keeping	E_T	TE
Object Sub-Difficulty 1	S_{O1}	O1S
Object Sub-Difficulty 2	S_{O2}	O2S
Object Difficulty	S_O	O`S
Object Sub-Keeping 1	E_{O1}	O1E
Object Sub-Keeping 2	E_{O2}	O2E
Object Keeping	E_O	O`E
Quality Sub-Difficulty 1	S_{Q1}	Q1S
Quality Sub-Difficulty 2	S_{Q2}	Q2S
Quality Sub-Difficulty 3	S_{Q3}	Q3S
Quality Difficulty	S_Q	Q`S
Quality Sub-Keeping 1	E_{Q1}	Q1E
Quality Sub-Keeping 2	E_{Q2}	Q2E
Quality Sub-Keeping 3	E_{Q3}	Q3E
Quality Keeping	E_Q	Q`E

The remaining characteristics will be labeled in the same way as with the Basic Objective Structure. Object Sub-Difficulty, Quality Sub-Difficulty, Object Sub-Keeping etc. sometimes will be subsumed under the name sub-characteristics during evaluations.

5.2 Goodness: Concept and Characteristics

5.2.1 The Goodness Concept

In Sect. 2.3.2 “Base-Goals and Check-Goals”, we have explained the double requirement given for any project realization. For example, project costs should be as low as possible, but you are supposed to keep the budget. The degree of meeting each one of these two requirements is expressed by Difficulty and Keeping.

The Goodness of a project realization in the sense of this work consists in the degree of meeting both of these requirements. It will be measured by calculating the weighted mean of Difficulty and Keeping.

In order to express the Goodness of a project realization quantitatively, we calculate that weighted mean for every lowest-level subobjective and build another set of characteristics leading to the Project Goodness characteristic. Goal weights will be used for weighting, for Difficulty and Keeping separately, as outlined in Sect. 2.4.

The Goodness G of project realization regarding any one lowest-level subobjective U is

$$G_U = \frac{S_U \times W_{S_U} + E_U \times W_{E_U}}{W_{S_U} + W_{E_U}}$$

Please note: Difficulty or Keeping characteristics only show their respective aspect, whereas Goodness characteristics always combine both aspects. Goodness results from Difficulty and Keeping without further Partial Comparisons.

Actually, the characterization “Difficulty or Keeping of a subobjective, respectively” cannot be transferred literally to the new notion of Goodness, because “Goodness of a subobjective” would mean something different from the Goodness characteristic. The correct description of Goodness would be “Goodness of project realization regarding one subobjective”. To avoid this somewhat cumbersome description, we will preferably use the terms Cost Goodness, Time Goodness, etc.

5.2.2 Within the Basic Objective Structure

If the objective structure does not exceed that of Fig. 2.1, we get

Cost Goodness	$G_K = \frac{S_K \times W_{S_K} + E_K \times W_{E_K}}{W_{S_K} + W_{E_K}}$
Time Goodness	$G_T = \frac{S_T \times W_{S_T} + E_T \times W_{E_T}}{W_{S_T} + W_{E_T}}$
Object Goodness	$G_O = \frac{S_O \times W_{S_O} + E_O \times W_{E_O}}{W_{S_O} + W_{E_O}}$
Quality Goodness	$G_Q = \frac{S_Q \times W_{S_Q} + E_Q \times W_{E_Q}}{W_{S_Q} + W_{E_Q}}$

Linguistically, the term Quality Goodness is unsatisfactory. We could paraphrase it by choosing “Goodness regarding Quality”, “Acceptability Goodness”, “Realization Goodness” or some similar term; but this might as well lead to misunderstanding because of the significance and importance of the term “quality”.

The remaining Goodness characteristics are

$$\text{Process Goodness } G_A = \frac{S_K \times W_{S_K} + E_K \times W_{E_K} + S_T \times W_{S_T} + E_T \times W_{E_T}}{W_{S_K} + W_{E_K} + W_{S_T} + W_{E_T}}$$

$$\text{Performance Goodness } G_L = \frac{S_O \times W_{S_O} + E_O \times W_{E_O} + S_Q \times W_{S_Q} + E_Q \times W_{E_Q}}{W_{S_O} + W_{E_O} + W_{S_Q} + W_{E_Q}}$$

Project Goodness

$$G_P = \frac{S_K \times W_{S_K} + E_K \times W_{E_K} + S_T \times W_{S_T} + E_T \times W_{E_T} + S_O \times W_{S_O} + E_O \times W_{E_O} + S_Q \times W_{S_Q} + E_Q \times W_{E_Q}}{W_{S_K} + W_{E_K} + W_{S_T} + W_{E_T} + W_{S_O} + W_{E_O} + W_{S_Q} + W_{E_Q}}$$

Again, we want to continue the symbols list:

	Math.	DP
Cost Goodness	G_K	KG
Time Goodness	G_T	TG
Object Goodness	G_O	OG
Quality Goodness	G_Q	QG
Process Goodness	G_A	AG
Performance Goodness	G_L	LG
Project Goodness	G_P	PG

Figure 5.2 illustrates these Goodness characteristics and their relationship to the unweighted characteristics S and E of the Partial Comparisons. Again, underneath each of the Goodness characteristics, the mathematical notation is given in the left-hand corner, the DP notation in the right-hand corner.

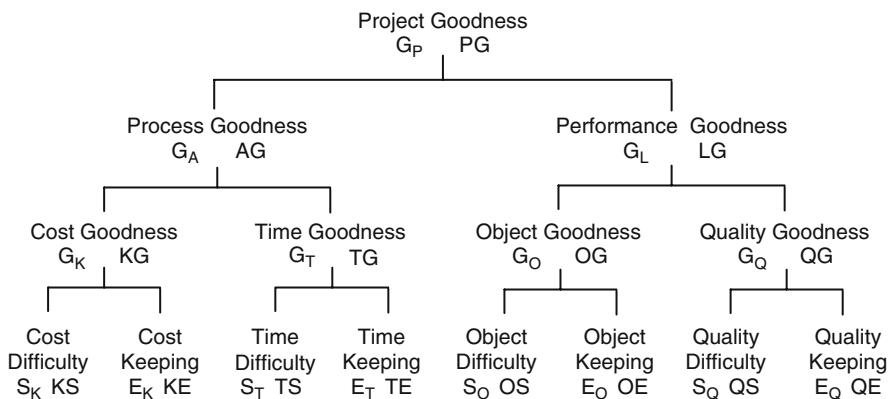


Fig. 5.2 Goodness characteristics structure out of the unweighted Difficulty and Keeping characteristics for the Basic Objective Structure

5.2.3 Within an Extended Objective Structure

As Goodness is a mean by definition, an objective structure extension does not imply any changes.

For every lowest-level subobjective, we calculate a separate Goodness, like we did with the Basic Objective Structure. For example, Difficulty and Keeping of the three quality subobjectives Q1, Q2, and Q3 from Fig. 2.3, namely S_{Q1} , S_{Q2} , S_{Q3} , E_{Q1} , E_{Q2} , and E_{Q3} , result in

$$\text{Quality Sub-Goodness 1 } G_{Q1} = \frac{S_{Q1} \times W_{S_{Q1}} + E_{Q1} \times W_{E_{Q1}}}{W_{S_{Q1}} + W_{E_{Q1}}}$$

$$\text{Quality Sub-Goodness 2 } G_{Q2} = \frac{S_{Q2} \times W_{S_{Q2}} + E_{Q2} \times W_{E_{Q2}}}{W_{S_{Q2}} + W_{E_{Q2}}}$$

$$\text{Quality Sub-Goodness 3 } G_{Q3} = \frac{S_{Q3} \times W_{S_{Q3}} + E_{Q3} \times W_{E_{Q3}}}{W_{S_{Q3}} + W_{E_{Q3}}}$$

The actual quality subobjectives in the case of a structure extension will also have their own significant names. Thus the respective Quality Sub-Goodness G_{Q1} , G_{Q2} , and G_{Q3} can easily be distinguished from the overall Quality Goodness G_Q . The overall Quality Goodness is given as

$$G_Q = \frac{S_{Q1} \times W_{S_{Q1}} + E_{Q1} \times W_{E_{Q1}} + S_{Q2} \times W_{S_{Q2}} + E_{Q2} \times W_{E_{Q2}} + S_{Q3} \times W_{S_{Q3}} + E_{Q3} \times W_{E_{Q3}}}{W_{S_{Q1}} + W_{E_{Q1}} + W_{S_{Q2}} + W_{E_{Q2}} + W_{S_{Q3}} + W_{E_{Q3}}}$$

If the objective structure has been extended by more than one level, correspondingly we will need more calculation steps with appropriate terms, starting with the lowest level, in order to reach the situation illustrated in Fig. 2.2.

5.3 Classification of Terms

Project Goodness is the top term of Goodness characteristics. Fig. 5.3 illustrates its relationship with the concepts of Project Excellence and the Project Management Award, respectively [30, 94], and the concept of Project Success. Some of the terms show annotations made by me.

The concept of Fig. 5.3 associates Project Goodness with “Other criteria”. Nominal/actual value comparisons, listed alongside, might be useful in addition to Project Goodness as an evaluation criterion, because in the context of Project Goodness, nominal/actual value comparison results will be appraised only in relation to similar projects, but not in relation to fulfilling any fictitious or real contract. The dots alongside Project Goodness in Fig. 5.3 refer to the possibility of using further – e.g., branch specific – characteristics as criteria.

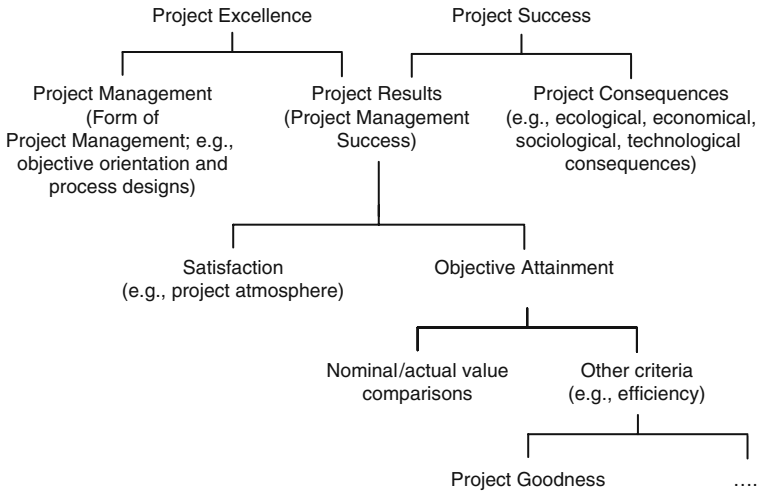


Fig. 5.3 Integration of Project Goodness in the concept of Project Excellence and Project Success

The importance of project comparisons goes farther than the calculation of Project Goodness. Having access to observations about Satisfaction, we can use project comparisons to appraise Project Management Success [92–94].

With additional data concerning project management realization, we could do comparative evaluations of Project Excellence, with further project consequences data, of Project Success and even a possible top-level combination of excellence and success. Possible fields of use of project comparisons only depend on the availability of appropriate data. We will hear more about this in Chap. 16.

Applying the three characteristics Goodness, Difficulty, and Keeping, you should bear in mind that only the topmost characteristic – Project Goodness, Project Difficulty, and Project Keeping, respectively, – contains all the relevant features of project realization. We should not draw conclusions concerning the overall project from sub-characteristics.

For example, low Process Goodness could be combined with outstanding Performance Goodness, and vice versa. The same holds for other sub-characteristics.

Of course, comparisons regarding only parts, i.e. single aspects, of projects or the objective structure can be legitimate and useful. However, they must not be mistaken as an overall project evaluation.

Finally, we want to caution you about interpreting Goodness values as project team performance only and so to attribute low Project Goodness to the team alone [66]. The Goodness determined is the difference to guide values that cannot be explained by influences used and may have various causes. The proportion due to the project team is unknown.

Chapter 6

Comparison Typology

6.1 Types of Comparisons by Data Combinations

Doing a parametric Partial Comparison, we seek or establish a relationship between one or more influence variables and a target variable. The influences as well as the target can be either initial values or final values. This situation formally gives us four combinations that shall be enumerated by type according to Fig. 6.1.

		Influence variable values are	
		Final values	Initial values
Target variable values are	Final values	Type 1	Type 2
	Initial values	Type 3	Type 4

Fig. 6.1 Data combination types of comparisons

Strictly speaking, this classification, as well as others to come, is valid only for Partial Comparisons, not for Total Comparisons, because there you could mix various types of Partial Comparisons. As such a mixing does not make sense, however, we will assume the same types for all Partial Comparisons of a Total Comparison and so can apply this classification to Total Comparisons, too.

Also, we want to assume that the reference date of the goal weights corresponds to the reference date of the influences concerned. If the influences are initial values, the goal weights should be initial values, too; the same holds for final values. In this way, by referring to the influences, we can also classify all characteristics as either initial or final values.

Type 1 is the most straightforward comparison type and probably the easiest to understand. Here the final status of projects will be compared by means of final values of target and influence variables. An example has been shown in Figs. 3.1 to 3.6 and the corresponding text.

The counterpart is type 4, where targets as well as influences are initial values. In a certain sense, here we will compare plans to plans (more exactly, the initial

relative dimensions of projects) without taking into account later project results. Such a comparison might indicate, for example, whether the planning procedure of a planning agency has been changed in relation to initial influence values of projects. The practical importance of comparison type 4, however, will be rather low.

With comparison type 2, the situation is different. Here the influence values, same as with type 4, are initial values, but the target values are final values. So we get a prognosis tool: Starting with initial values of influence variables for a similar new project, we can calculate the probable final value of the target variable and the realization probability for any initial values of the target. We will talk about this in greater detail in Sects. 6.3 and 6.4.

The least obvious of the four comparison types, and probably the one with the least practical importance, is type 3. Here the target values are initial values, the influence values, however, are final values. Formally, this is the counterpart to type 2, i.e., a comparison of former initial values of target variables, using final values of the influence variables. Potentially, this might be used in rare cases where you want to reconstruct former important target values for an already finished project, whose plans have been lost.

Comparison types 3 and 4 refer to project results stipulated and as such can show only the Difficulty, not the Keeping or the Goodness of projects. Type 1 and type 2, however, refer to project results produced and thus give us the complete characteristics hierarchy; this is one more reason why they are more important than types 3 and 4.

Apart from the four comparison types mentioned, we might get other data combination types by using not only initial and final values, but also intermediate values of goals and parameters for parametric project comparisons. In the present work, however, this will not be the case.

The different comparison types lead to different guide values and characteristics. Thus our characteristics occur in different categories with equal structure, but differing values. Figure 6.2 illustrates scatter values and guide values for the types 1 to 4, preceded by their type number for distinction. The balance lines are indicated by short inclined lines.

Figure 6.2 is not meant for metric interpretation, but is an attempt at helping you to understand the concept. Like the examples there, every other comparison type will lead to its own characteristics category.

6.2 Including Quasi-Parameters

Goal weights and Difficulty of subobjectives, alternatively also goal values of the same project, in many ways have an impact on the running of a project. As an example, postulating an extremely short project duration may lead to relatively high project costs, or postulating extremely low project costs may lead to less Quality Keeping, etc. Of course, such a postulation primarily affects the goal concerned.

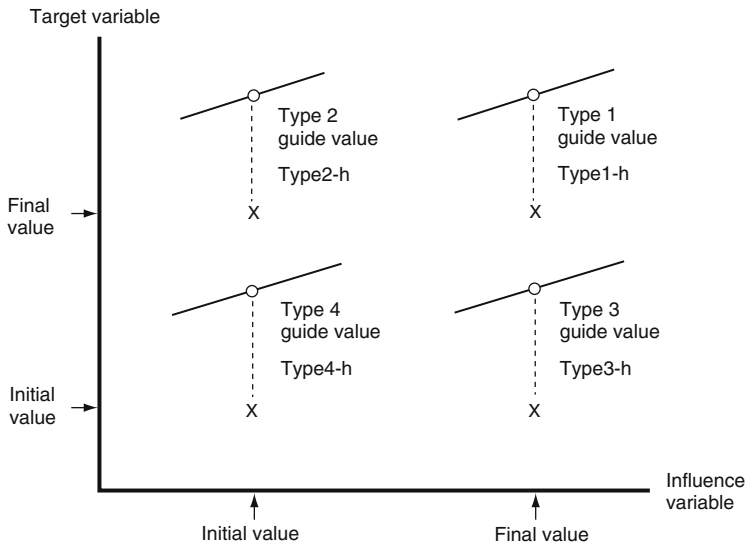


Fig. 6.2 Symbolic illustration of some comparison types

This is the reason why we want to call goal weights, Difficulty, and the other goals themselves “quasi-parameters”, as already mentioned in Sect. 3.2. Here, the influence of a goal weight need not correspond to that of the Difficulty. A specific Difficulty value may be the consequence of a corresponding goal weight, but can as well build up without it, e.g., by over- or underestimating project tasks.

Using goals as quasi-parameters in a Partial Comparison may lead to errors because these goals are directly influenced by parameters. Thus the situation may become more intricate than when using Difficulty characteristics, where parameter dependence is only indirect.

At least there exists a possibility to see goals as quasi-parameters, too, and Sect. 14.3 will show an example.

Goals and goal weights are to be treated like ordinary parameters, except when you want to use guide values of goals as quasi-parameters; in this case, the situation is the same as with Difficulty characteristics. Taking Difficulty characteristics as quasi-parameters usually implies getting new comparison types.

This is caused by the fact that in a Partial Comparison we cannot use the Difficulty resulting from a guide value as a quasi-parameter for calculating this same guide value, because it is not yet known. Rather, we have to use a Difficulty form from a previous comparison.

We could only use the Difficulty of another subobjective, having already done the corresponding Partial Comparison in the course of starting a Total Comparison. Even then, however, not all higher-level Difficulty characteristics of this Total Comparison are available. So generally we have to fall back on a previous comparison.

Example: In a first Partial Comparison without Difficulty influence, e.g. of type 2, we have to calculate type 2 guide values and so a type 2 Difficulty. Doing a second

Partial Comparison at the end of the project, calling it type 5, we can use this type 2 Difficulty as an additional quasi-parameter to calculate type 5 guide values and type 5 characteristics, including, of course, a type 5 Difficulty.

So only type 5 values take into account the influence of Difficulty, here of type 2 Difficulty. We need the new type number 5 because type 1 by definition contains only final values, but the Difficulty influence has an earlier reference date.

Having limited ourselves to initial and final values, this earlier reference date has to be the project start. Thus with a type 5 comparison, we take into account the influence of initial values of Difficulty characteristics, apart from other influences. How to calculate these initial values will be explained in Sect. 6.4.

Formally, type 2 and type 5 comparisons are different in so far that only type 5 comparisons take into account the Difficulty as a quasi-parameter. This difference may be undesirable when aiming at exactly corresponding comparisons, i.e. the same parameters in both comparisons. In the case that for both reference dates – the type 2 date and the type 5 date – the quasi-parameter Difficulty is supposed to be used, we have to follow up the type 2 comparison with a further comparison immediately afterwards, i.e. still on the type 2 reference date. This additional comparison will be named type 6.

In this type 6 comparison, the type 2 Difficulty will be used as an additional quasi-parameter, the same way as in the type 5 comparison, and from the type 6 comparison will result type 6 guide values and type 6 characteristics. In the final type 5 comparison, that now is the third one to be executed, not the type 2 Difficulty, but the type 6 Difficulty will be introduced as a quasi-parameter.

So we now have found an analogy between type 6 and type 5 comparisons. In this case, the type 2 comparison only has secondary importance as a tool to be used. Therefore, doing such auxiliary comparisons will be limited to those of the base characteristics that will have their Difficulty used in the type 6 comparisons as a quasi-parameter.

Contrary to the type 5 comparison, however, the type 6 comparison is not an exact calculation. Type 2 and type 6 comparison by definition should correspond to the same reference date, but the type 2 Difficulty used as a quasi-parameter has a value different from the resulting type 6 Difficulty.

This is a logical contradiction, as at any moment, having calculated correct guide values, only one Difficulty value can be correct. With type 6 comparisons, calculating correct guide values is not possible; only the approximation described can be reached.

To resume: comparison types 5 and 6 contain Difficulty characteristics calculated from a previous comparison as additional quasi-parameters. With type 5, the reference date of this additional quasi-parameter differs from the reference date of the other influence values. Type 6 does not have this difference, but considering the additional influences, it is not exact, but only an approximate comparison.

In the case where comparisons with intermediate values of goals and parameters have been added to the type numbers 1–4, the new types may of course be named differently. In Sect. 8.7, we will demonstrate an example for comparison types 5 and 6.

6.3 Descriptive and Inferential Comparisons

The balance functions specify interrelations between influence and target variables in a given set of similar projects. It is plausible, as we mentioned previously, to use balance functions, calculated for one set of projects, for deducing data of another similar project not contained in this set. If this project is still to come, we therefore make a prognosis.

This special use of balance functions extends the notion of comparisons. This is why we want to distinguish between descriptive and inferential comparisons. Every inferential comparison also contains a descriptive one because otherwise we would not have a balance function, but it exceeds the descriptive comparison. More details are going to follow in the next section.

Inferential project comparisons have to be interpreted cautiously, because projects scarcely run according to fixed rules like physical or biological processes do. Furthermore, we have to differentiate between interpolation and extrapolation. With interpolation, the influence values of the project not involved in calculating the balance function is lying inside the range of the other projects' influence values; with extrapolation, at least one of them is lying outside.

Extrapolation increases the error risk, as the balance functions only approximate the true – and unknown – relationships. Not even inside the range covered by calculating the balance function the true relationships, which probably are much more complex, are really known, and outside this range they might be radically changed, deforming the balance function, too.

Also without this additional risk, however, distinguishing between descriptive and inferential comparisons is important, being decisive for whether and how the results can be used. Statistical science is concerned with formulating conditions that allow inferences from known to unknown situations; we will detail the conditions suitable for our case in Sects. 8.4, 8.5 and 11.5.

6.4 Initial and Final Comparisons

Regular applications usually will be limited to a few of the comparison types mentioned. Points of special interest may be comparing projects in an early phase in order to assist decisions and planning, or else comparing projects at the end of a project for documentation and experience collection.

We want to call these two comparison types initial comparison and final comparison, respectively. The simpler type, final comparison, can be characterized as follows:

Starting point is the descriptive type 1 comparison based on final values of target and influence variables. Difficulty characteristics being used, too, we get a descriptive type 5 comparison where the Difficulty influence variables are initial values.

The initial comparison is a lot more complicated than the final comparison, particularly so as we have to differentiate between two more versions, the proper and the improper initial comparison. Their difference is based on other considerations than the difference between final comparisons type 1 and type 5.

During early stages of a project, i.e. for an initial comparison, the types of comparison most suitable are inferential comparisons type 2 or sometimes type 6. These types contain the elements that promise the best prognoses for a new project and result in a proper initial comparison.

First, we want to detail an example for a type 2 comparison; to this end, we imagine standing at the start of such a new project.

As a prerequisite for an initial comparison, we have to execute descriptive type 2 Partial Comparisons of completed projects. These projects we want to call reference projects. The balance functions of the type 2 comparisons will give us type 2 guide values for the reference projects.

We, however, are looking for a prognosis for the new project. This project could not participate in the descriptive type 2 comparisons of the reference projects, as we know the initial values of the influence variables and possibly initial values of target variables, but not the final values of the target variables necessary for type 2 comparisons.

Now we insert the initial values of the influence variables into the balance functions of the type 2 comparisons for the reference projects and from this calculate hypothetical guide values for the new project, calling them initial guide values in order to distinguish them from the type 2 guide values of the reference projects. This step extends the type 2 comparisons of reference projects to inferential comparisons which will be called initial comparison of the new project.

The initial guide values are the prognosis; here we make an inference from the reference projects to the new project.

This deduction can not be avoided, but it is risky for the reasons mentioned in the previous section. Type 2 guide values and initial guide value stem from the same balance function; but the type 2 guide value is a real, the initial guide value a hypothetical comparison result, as possible special properties of the new project have not been incorporated in the balance function.

You might prefer including the new project with its initial values of influence and target variables already in the descriptive type 2 comparisons. Balance functions and type 2 guide values, however, based on final values of target variables, would be distorted; the result would not be more reliable.

By means of the separate initial guide values, we now can evaluate the initial values of the target variables of the new project. The initial h' deviation of the new project, divided by the standard deviation of the descriptive type 2 comparison scatter values of the reference projects and added to the scale constant 5, will result in the initial Difficulty for a Base-Goal.

Similarly, an initial Keeping can be calculated. For example, initial Check-Goal values may result from assuming that the future final Base-Goal values should match the initial Base-Goal values. This condition will give us the following initial values, e.g. with Check-Goals being differences or ratios of final Base-Goal value and initial Base-Goal value:

	Check-Goal	Initial Check-Goal Value
Difference	final Base-Goal value – initial Base-Goal value	0
Ratio	final Base-Goal value/initial Base-Goal value	1

The evaluation of these initial Check-Goal values is similar to that of initial Base-Goal values. If the reference projects had final Check-Goal values worse than 0 or 1, respectively, we will get an initial Keeping greater than 5, otherwise less than 5. Thus, Keeping and the whole hierarchy of characteristics can be used for an initial evaluation of a new project.

This initial evaluation of a new project is the purpose of initial comparisons. The values of this characteristics category tell us how ambitious the requirements are if the project realization will be judged by the prognosis, the initial guide values. Type 2 comparisons are needed only during the process and do not explicitly appear in the evaluation.

In an example that will be shown in Chap. 12, we will gain additional information: as we have mentioned before, we can draw conclusions from the frequency distribution of values of a Partial Comparison as to their realization probability. Of course, with an initial comparison, this is a point of major interest. Mathematical relationships will be shown in Sect. 8.5.

If needed, we can follow up the inferential type 2 comparison with an inferential type 6 comparison, in spite of its being not really exact. Thus approximately taking into account Difficulty influences already in the prognosis and maybe in defining the project objectives would be an advantage; having to execute yet another series of Partial Comparisons might be cumbersome. We might proceed as follows:

Having finished the first initial comparison as an inferential type 2 comparison, we do a second initial comparison as an inferential type 6 comparison in the same way. Here we get type 6 balance functions as explained in Sect. 6.2. The first initial Difficulty values of the new project resulting from the first initial comparison will be used as corresponding Difficulty influences – having been transformed, if necessary –, the other initial influence values of the new project will be used as corresponding influence values for the type 6 balance functions.

The type 6 balance functions will result in second initial guide values, second initial characteristic values, etc., for the new project. The first initial guide values and first initial characteristic values from the inferential type 2 comparisons now are outdated and have lost their importance. Of course, the second initial guide values and second initial characteristic values still are rather hypothetical; the corresponding uncertainty even will be increased by the inexactness of type 6 comparisons.

Now we have finished describing the proper initial comparison. Its variant, the improper initial comparison, is comparatively easy to explain.

As we have demonstrated above, the proper initial comparison is based on type 2 and possible additional type 6 comparisons, i.e. comparison types different from the type 1 or type 5 comparisons used for final comparisons. This is a time-consuming

procedure: for proper initial Total Comparisons, we have to execute at least a complete series of type 2 Partial Comparisons, maybe even of type 6 comparisons, too.

Therefore, we might want to use existing type 1 comparisons, and possibly type 5 comparisons, in order to do initial comparisons. In both of these cases, one series of Partial Comparisons can be left out.

To this end, we do not insert the initial influence values of the new project into type 2 balance functions created for this purpose, but into existing balance functions of type 1 comparisons, and so calculate our characteristics. If needed, we may use the resulting first values of initial Difficulty – after transformation, if necessary – as corresponding Difficulty influence variables in type 5 comparisons and thus get second initial guide values, second initial characteristic values, etc.

Using type 1 and type 5 comparisons instead of type 2 and type 6 comparisons, however, we get a systematic error: we ignore the fact that the influence variables, too, are subject to changes during the running of a project; thus we adulterate the prognosis.

The magnitude of the effect of this distortion will vary between users. Anyway, it may be useful to point out the bias by means of the name “improper initial comparison”.

To resume:

- (Proper) initial comparison: Inferential type 2 comparison or a sequence of type 2 and type 6.
- Improper initial comparison: Inferential type 1 comparison or a sequence of type 1 and type 5.
- Final comparison: Descriptive type 1 or type 5 comparison.

Figure 6.3 shows all comparison types with their relationships. The dashed arrows indicate the sequence of comparisons to be executed.

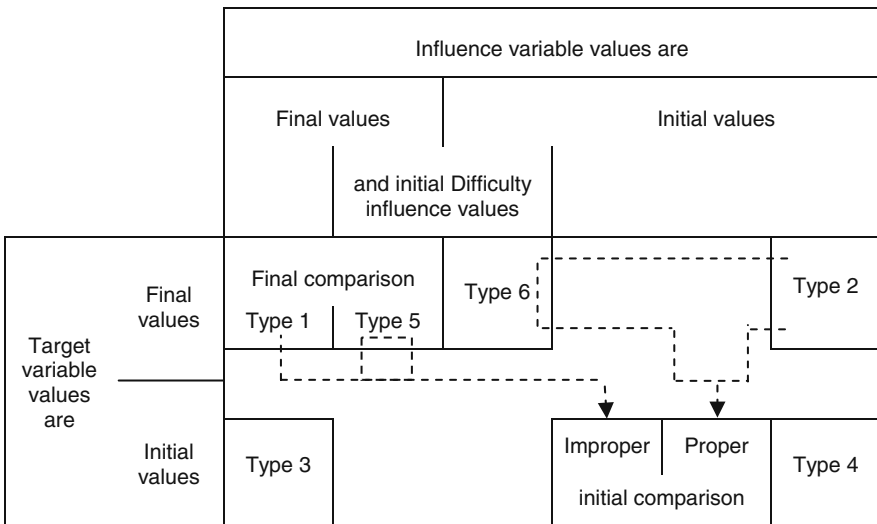


Fig. 6.3 Overview of types

For example, an improper initial comparison implies that either a type 1 comparison only or a type 1 and ensuing type 5 comparison be executed. Accordingly, the corresponding arrow originating from the type 1 box either passes the type 5 box or makes the deviation through it.

In the same way, one arrow aims from the type 2 box directly into the proper initial comparison box, whereas a second one leads through the additional type 6 comparison box. These deviations are necessary whenever influence variables derived from Difficulty characteristics are to be used.

6.5 Comprehensive Terminology

The type of comparison and the selection of projects, goals, and parameters used have significant impact on the comparison results and therefore have to be documented together with these results.

A possibility used here is to note initial or final comparison when citing an evaluation. This is followed by the projects used for the descriptive comparison in parentheses and, if necessary, the new project of the inferential comparison behind the parenthesis. Using possible abbreviations, this might be, for example,

InitialCo (P003..P007) P009,

meaning an initial comparison consisting of a descriptive comparison of projects P003, P004, P005, P006, and P007, and the deduction for the new project P009 not involved in the descriptive comparison.

If target and influence variables are not being named in the evaluation itself or the accompanying documentation, we should add further information, at least with Partial Comparisons, such as

goal (parameter).

Thus informing about type, projects, goal, as well as parameter and quasi-parameter forms, the comparison has got a unique identification, apart from possible transformations. If necessary, transformations can be designated by giving the balance function.

If required, we might add a sequential number or a label identifying the Total Comparison. This is useful if the underlying file of projects varies over the time, e.g., including further projects completed in the meantime.

Thus, the sequential numbering indicates the corresponding status of the file of projects. Here, the letter *m* will be used for this sequential numbering: $m = 1, 2, 3, 4, \dots$; *m* is unlimited and can have several parts in order to show Total Comparison and Partial Comparison number or something like that, or contain a date. We will call *m* a label.

Adding the comparison type number introduced as an organizing device is not necessary. Furthermore, we may leave out the “initial” or “final” with the goal form,

as it always will be a final value in final comparisons, an initial value compared with final values in initial comparisons.

Example: Figs. 3.1, 3.2, 3.3 and 3.4 show an example that is a descriptive type 1 comparison, i.e., a final comparison. Abbreviated, this would give

FinalCo ($P_1 \dots P_4$) project duration (final number of parts).

Chapter 7

Correction for Cost, Price, and Working-Time Index

One of the tasks of Project Comparison Technique is comparing projects over long periods of time. Doing this, we have to take into account general changes in costs, prices, and working-times.

This can be achieved by relating the original cost, price, or working-time value, according to its year, to an index, i.e. to the corresponding value of a time series, thereby converting the value to that of a certain base year.

If, as usual, the index is given by adding 100 to the percentage of currency depreciation (here also: time depreciation), we get

$$\text{index corrected variable} = \text{original variable} \times \frac{100}{\text{index value}}$$

In Germany, currency depreciation indices are edited by “Statistisches Bundesamt” and published annually (“Statistische Jahrbuecher”). They are sorted by branch and other criteria in order to allow a certain amount of choice.

Sometimes, the indices are being changed to a different base year. If necessary, they have to be converted in continuing series with a uniform base (concatenated). You will find recommendations of how to do this in literature [36].

Usually, the procedure is a multiplication. I_c being the original index value for the year of the base change and I' the index with changed base, we get the continuation of the original index I as

$$I = \frac{I_c \times I'}{100}$$

The risk of concatenated indices being slightly inexact after several catenation steps, in spite of correct calculation, presumably has to be borne [62].

For comparing projects over long periods of time, we will need at least one cost, price, and working-time index, respectively. We will distinguish them by adding a sequential number q :

$$I_q \quad \text{with} \quad q = 1, 2, 3, \dots$$

For each project, we will note two special values of each of the indices, namely those for the years of initial and final values of the project, respectively. These collected forms we will call initial cost index value, initial price index value, initial working-time index value, final cost index value, etc.

Naturally, published index values only relate to the past; the time series usually terminate one to two years before the present one. If we are collecting project data in the remote past, this fact is not relevant, but for index correction of current cost and price values the indices have to be extrapolated into the present.

There are numerical procedures for extrapolation and prognosis. The projects investigated during the present work, however, belong to a period of relatively small inflation. Therefore, as far as this extrapolation is concerned, only my personal estimation was used, based on public information on the development of costs and prices.

This estimation was improved corresponding to publication of further information, but was applied only on project data collected afterwards. There was no retrospective correction of estimation results already processed. The inexactness caused hereby, avoidable in principle, is irrelevant in relation to that from other sources.

The working-time index used in this work (cf. Sect. 10.2.2) has been derived from data got by courtesy of the German Bundesanstalt fuer Arbeit (Institut fuer Arbeitsmarkt- und Berufsforschung). It refers to the development of the reciprocal annual working-time and has been calculated only after the projects concerned had been finished, so extrapolation was not necessary.

Chapter 8

Mathematical Issues of Partial Comparisons

8.1 Balance Function

The balance function can be determined graphically only in some favorable cases and for single influence variables; usually, we will achieve this end by means of DP programs based on regression analysis.

Regression analysis (a more appropriate name would be “influence analysis”) is a widely used statistical tool to establish a formal relationship between a dependent variable assumed to be influenced and one or several independent variables assumed to possibly influence the dependent variable. Further effects that are not part of the investigation are supposed to exist and to cause a random scattering of the dependent variable values.

The relationship found will be given in the form of a balance function, often called estimating function. Even yielding a good result, however, regression analysis does not explain the causality between the variables concerned, does not even show its existence. What is shown is only the manner and the stringency of how several events coincide.

Interpretation as cause and effect and explaining the supposed relationship is subject to expert knowledge. This is the reason why we have stressed the need for a plausible cause-and-effect relation between parameters and goals in Chap. 3.

There are several mathematical procedures for doing regression analysis, the so-called least squares method being the most popular one because of its being well-known and having certain statistical qualities. Virtually every statistics program package contains such a module, and every book on statistics will set out the method.

In a more moderate form it is also contained in spreadsheet programs such as SIPLAN [69] and EXCEL [26], which we will revert to in Chap. 15. We, too, will use the least squares method.

In Chap. 3, Partial Comparison, we have used the scatter value h , i.e. the vertical difference between a model value observed and its reference point on the balance function, for comparing projects. The least squares method determines the balance

function in such a way that the sum (Σ) of the squared scatter values h_i of all n projects of a descriptive comparison will be minimized:

$$\sum_{i=1}^n (h_i^2) = \text{Minimum} .$$

Literature [82] demonstrates that this condition also balances positive and negative h values, giving 0 as the mean of all scatter values h_i of a Partial Comparison.

Therefore, the least squares method fulfills the “intuitive” requirement of the balance line having a neutral position between positive and negative scatter values and lends itself as a calculation tool for project comparisons. We will adapt the terminology, using the terms target and influence (variable) instead of dependent and independent variable.

We want to sketch the analytical steps for establishing a balance function by means of a simple balance line, like the one used in Figs. 3.1 to 3.4. Generally, the equation for a straight line is

$$y = a + bx .$$

Let us suppose that x is an influence variable value and y a value of the target variable influenced by it. They may have a linear relationship with scatter values h superimposed, as we have presented in Sects. 3.3 and 3.4.

Thus, we can decompose any value y_i observed in a project i into

$$y_i = a + bx_i + h_i .$$

In this decomposition, $a + bx$ is the balance line and the value $a + bx_i$ is the guide value of project i . We will characterize balance line and guide value by a hat (circumflex, $\hat{}$) in order to distinguish them from observed values y_i :

$$\begin{array}{ll} \text{Balance line} & \hat{y} = a + bx \\ \text{Guide value} & \hat{y}_i = a + bx_i . \end{array}$$

Figure 8.1 graphically shows this decomposition, a being the intercept, i.e. the height of the intersection between balance line and ordinate axis, and b the slope of the balance line.

a is the mean of all the effects on y that have not been incorporated in one of the influence variables. This block of not identified effects will not be decomposed in the calculation; therefore, we will call a the block value of the Partial Comparison. In statistics books, a often will be called the (y-axis) intercept.

The b value indicates whether the influence variable has a strong or a weak effect on the target variable, which is why we want to call b the influence weight. Contrary to goal weights that can be chosen arbitrarily, influence weights are automatic

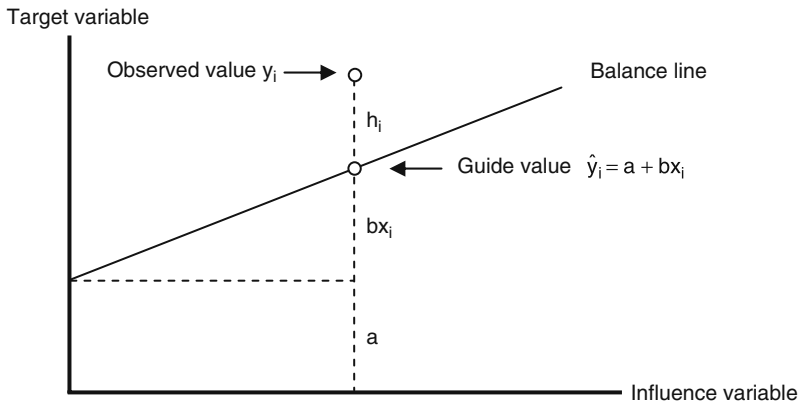


Fig. 8.1 Decomposition of an observed value y_i into guide value \hat{y}_i and scatter value h_i

results of regression analysis. In statistics books, they often are called regression coefficients.

Together, block value and scatter value represent the effects that are not identified; the block value as their mean, as mentioned before, and the scatter value as respective deviation from this mean. Statistics books often call the scatter value residual.

For better understanding of the significance of block value and scatter value, you may want to consider the special case of an influence variable x having no effect at all on the target variable y . In this case, $b = 0$ and so $\hat{y} = a$. The balance line would run horizontally at the height of the mean of target variable y , and the values of the target variable would scatter around this horizontal line, which corresponds to the case treated in Sect. 3.9.

The least squares method always requires establishing a and b in such a way that the minimum condition mentioned at the beginning of this section will be fulfilled. This task can be performed using differential calculus; the general result is [69, 98]:

$$b = \frac{n \times \sum(x_i y_i) - \sum x_i \times \sum y_i}{n \times \sum(x_i^2) - (\sum x_i)^2}$$

$$a = \frac{\sum y_i - b \times \sum x_i}{n}$$

Here, the Σ signs for summing up always are meant to run over all projects of a descriptive Partial Comparison, same as in the minimum condition mentioned before.

These equations for a and b are defining the balance line. By inserting the necessary sums of observed values x_i and y_i , we can calculate b , and afterwards, a and the guide values \hat{y}_i .

DP programs will deal with the task of calculating a and b. We need not worry about how to calculate these and often also other useful variables, for example guide values or scatter values of the respective projects.

Now we can complete the calculation of the example in Figs. 3.1, 3.2, 3.3 and 3.4. There, we have

$$a = 13.8084 \quad b = 0.0866 ,$$

therefore

balance line:

$$\text{final project duration} = 13.8 + 0.0866 \times \text{final number of parts.}$$

This equation is valid for this one fictitious example only.

Now, we want to extend our considerations. So far, talking about the least squares method, we have assumed having the special case of a single influence variable and a corresponding decomposition of any observed value y_i into

$$y_i = a + bx_i + h_i .$$

In the reflections to follow, however, we want to assume the general case of having several influence variables that are independent of each other, and whose observed values we want to name $x_{i1}, x_{i2}, x_{i3}, \dots, x_{ip}$. Then, the decomposition takes the form [99]

$$y_i = a + b_1x_{i1} + b_2x_{i2} + b_3x_{i3} + \dots + b_px_{ip} + h_i$$

or

$$y_i = a + \sum_{j=1}^p (b_jx_{ij}) + h_i$$

with

$$\begin{array}{ll} i = 1, \dots, n & \text{project number,} \\ j = 1, \dots, p & \text{influence number.} \end{array}$$

Again, n is the total number of projects and p the total number of influence variables in the Partial Comparison (p is not connected in any way with the letter P for projects, but is derived from the word parameter). Here, the sum Σ comprises the total number of influence variables. We have to suppose an approximately linear relationship between each one of these influence variables and the target variable.

This approach is called multiple regression. Although the decomposition is more complicated, the solution method is more or less the same as in the simple case. So we have got a powerful tool for project analysis.

Working with projects, we will meet with both identified and unidentified influences as a mixture of effects that is hard to unravel. The great – maybe even genial – idea of regression analysis, which already the well-known mathematician C.F.Gauss worked upon, tells us how to separate these two types of influences. This stands behind quantifying influence weights, block value, and scatter values (cf. Fig. 8.2).

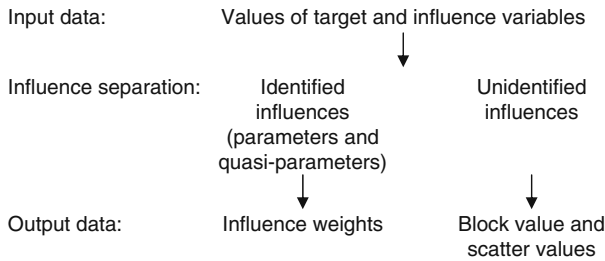


Fig. 8.2 Influence separation in regression analysis

Admittedly, we must not forget that we only are considering a model, not the true relationships of our projects that are far more sophisticated. So, for example, the block value of our model may be a negative value, i.e. extrapolating influence values to zero might lead to negative target values, thus seemingly contradicting reality.

All the same, we can rely on the model; the apparent contradiction only arises from extrapolating the model outside its valid range. We have warned you against doing this already in Sects. 6.3 and 6.4. The model is valid only inside the range of project values it is based upon.

Now some more comments on terminology:

In analytical considerations assuming linear relationships, i.e. models like the one in this chapter, we want to designate influence variables by x , target variables by y . On the other hand, dealing with real project values, we can not always assume linear relationships, so we will use capital letters X for parameter forms, Y for goal forms.

For the sake of clearness, goal weights, Difficulty characteristics and goals will keep their familiar designations S (Difficulty), W (weight) and Y (goal), even being used as quasi-parameters. Already in Sect. 6.2, we have mentioned possible problems with using goals as quasi-parameters.

The respective influences, whose number is p , of a Partial Comparison will be distinguished by a sequential number j . Likewise, we want to distinguish the respective target variables, whose number may be z , by a sequential number k , in view of later Total Comparisons.

In our Fig. 3.5 example, we have implicitly used the number k for adjusted scatter values. If necessary, we might call the final project duration Y_1 and the final project costs Y_2 . The only influence variable present, the final number of parts, could be X or X_1 .

Whenever the terms influence variable or target variable seem too bulky to be used in evaluations, they might be abbreviated by

$$\begin{aligned}\text{InfV} &= \text{influence variable} \\ \text{TargV} &= \text{target variable}\end{aligned}$$

8.2 Transformations

In Sect. 3.3, we have already mentioned that it may be necessary to transform project values. Now we want to investigate these transformations.

We are free to choose any transformation. We can transform a goal form or a parameter form only, or we can transform both of them, and we can use different transformations doing this. Often it is not easy to pre-estimate the effects of transformations; we will have to use scatter plots.

Transformations creating specific curvatures on linear variables, such as reciprocal, logarithm, and power functions, are appropriate for linearizing relationships, because they might neutralize possible opposite curvatures of the project value distribution. The following transformations will be used in evaluations to come, if necessary:

$$\begin{aligned}1/X_j &= \text{reciprocal of } X_j \\ \ln X_j &= \text{natural logarithm of } X_j \\ \exp X_j &= \text{exponentiation of } X_j \text{ with base } e \text{ of natural logarithms} \\ \sqrt{X_j} &= \text{square root of } X_j \\ X_j^2 &= X_j \text{ squared} \\ X_j^{0.2} &= X_j \text{ to the power of } 0.2 (= \sqrt[5]{X_j}) \\ \ln Y_k &= \text{natural logarithm of } Y_k \\ \sqrt{Y_k} &= \text{square root of } Y_k\end{aligned}$$

So, parameter forms and goal forms transformed in this way can enter calculations as influence variables and target variables, respectively, as well as X_j and Y_k .

If we want to characterize target and influence variables of a specific goal or parameter in a general way, without knowing whether or how it will have to be transformed, we will use an apostrophe added to the respective collected form name, e.g.

$$\begin{aligned}X_j' &= \text{unspecified influence variable of parameter form } X_j \\ Y_k' &= \text{unspecified target variable of goal form } Y_k\end{aligned}$$

Certain numerical values cannot be transformed in every way. For example, zero has no reciprocal that could be used, negative numbers have no real square root values etc. Most of these particular numbers can be avoided by adequately defining the respective collected forms; with the rest, we may have to find an approximate substitute when they happen to appear.

For the data used in the present work, I have not changed the project value itself in such cases, intending to leave the original data base intact. Instead, an approximate practical value has been substituted for the unusable transformed value.

8.3 Standard Deviation of Scatter Values

As we have explained in Sect. 3.5.2 on Partial Comparison, we need the standard deviation s of all scatter values h to calculate Difficulty and Keeping of any lowest-level subobjective of the project.

This standard deviation – in the general case of multiple regression – has the form [70]

$$s = \sqrt{\frac{\sum(h_i^2)}{n - p - 1}} ,$$

n being the number of projects, p the number of influence variables, and i the sequential number of any one of the projects. If in a Partial Comparison no influence variable is used, as mentioned in Sect. 3.9, then $p=0$ and the denominator becomes $n-1$.

The sum Σ again is meant to sum up all n projects of the comparison. DP programs for regression analysis usually display the standard deviation of scatter values together with the regression results.

Looking at the standard deviation formula, we can see that the minimum number of projects in a Partial Comparison has to be $p+2$. If we had not two, but only one more project than the number of influence variables used, the standard deviation could not be calculated, its denominator being zero.

In evaluations, we may need an abbreviation:

$$\text{StDev} = \text{standard deviation of scatter values.}$$

8.4 Methodological Conditions and Steps of Parametric Partial Comparisons

As mentioned in Sect. 8.1, influence variables of a parametric Partial Comparison should be independent of each other [77]. Additionally, in statistics books describing the least squares method, we find postulations concerning the scatter value distribution [78].

According to these, scatter values have to appear at random, but they should have more or less the same variation for every influence value. There should not appear any pattern like, e.g., large scatter values for large influence values together with small scatter values for small influence values, or vice versa.

At every location of the balance function, the mean of all scattered target values of (hypothetical) similar projects at this point should be situated on the balance function. This means that there should be no global ascending or descending of the target values towards the right or left side of the chart, as well as no global “rainbow” or sagging compared to the balance function in vertical direction.

Fig. 8.3 Idealized scattering of a linear relationship

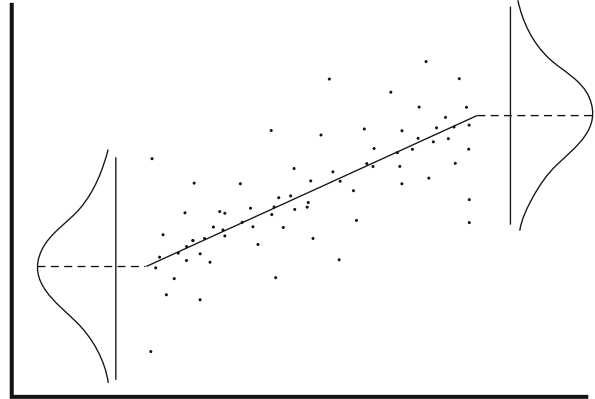


Figure 8.3 demonstrates in an idealized way how these conditions might be fulfilled for a single influence variable. Except from the balance line added and the distribution curves indicated at both sides, the figure is an idealized scatter plot conforming to Sect. 3.3. With this scatter plot, transformation would not be necessary.

As a comprehensive, rather simple means to check parametric Partial Comparisons, statistics books recommend the so-called residual analysis [40, 44, 81], which is a result plot looking similar to Fig. 8.3 without our additions. It is a scatter diagram, not of target against influence variables, but of scatter values against guide values of the target variable.

Here, the guide values of the target variable form the abscissa. This result plot (in statistical terms often called a residual plot) offers quick rough evaluation of the regression result also with multiple regression, i.e. using several influence variables in the balance function.

In this work, we will use scatter diagrams of Difficulty or Keeping values to this end, as they are part of the Partial Comparison and have a known relationship to the scatter values. Figure 8.4 shows an example of a Partial Comparison somewhat smaller than Fig. 8.3.

The values of such a plot scatter around an imagined line of value 5 and should fall between 2 and 8. Values outside the range from 2 to 8 are called outliers [40, 45].

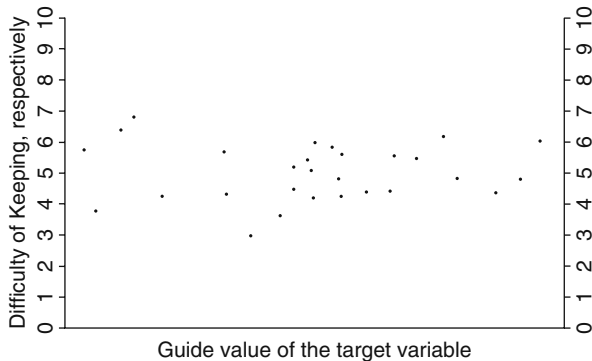


Fig. 8.4 Result plot of a Partial Comparison

However, even using a result plot it is not always easy to check whether the conditions mentioned at the beginning of this section can be met, especially with small numbers of projects; the more so as potential interdependence of parameters will not show. But not every violation of these conditions devaluates a Partial Comparison; we simply have to try to avoid gross mistakes throughout the process as far as possible.

Apart from this checking tool, there are statistical characteristics that can give us some further insight into Partial Comparisons, e.g. significance level, correlation, and coefficient of determination. Virtually all statistics programs automatically display these values along with the standard deviation of the scatter values [70].

The significance level [37, 42] is given as a percentage and represents the probability of the values resulting from pure chance instead of the supposed relationship. Therefore we want the significance level to be as low as possible.

Correlation is given as a number between -1 and 1 . Its square is the coefficient of determination, which is the characteristic we are interested in. It always is a number between 0 and 1 ; its value, e.g. 0.6543 , indicates that the corresponding percentage of variation of the target variable, here 65.43% , can be determined or “explained” by the influence variable(s). High coefficients of determination confirm the underlying technical considerations, subject to some reservations [75].

In some of the evaluations that will be shown later on, significance level and coefficient of determination are given with the abbreviations

- Signi = level of significance
- Deter = coefficient of determination

Admittedly, both of these characteristics might increase considerably if only few projects are being compared, so in this case they are no longer a useful indicator for the technical considerations being appropriate. Also by increasing the number of influence variables, the coefficient of determination can be raised arbitrarily [76].

Furthermore, neither these statistical characteristics nor the result plot can prevent errors concerning the causality between goals and parameters. The characteristics as well as the result plot only state numerical relationships, not the correctness of underlying assumptions.

In Sect. 11.5, we will look at some practical examples. For advanced issues, please have a look at statistics books [36, 42, 73, 98], especially as I am not a statistician by profession.

For doing parametric Partial Comparisons, I would recommend the following procedure:

- a) Choosing the participating projects carefully, taking into account the purpose of the investigation. If the purpose is the evaluation of a fixed group of similar projects, then of course no project may be left out, not even an outlier.
- b) Choosing the parameters to be used, checking their causal effect on the goal and their conceptual independence from each other.
- c) Checking the linearity of the relationship between the goal form chosen for the comparison and (each of) the chosen parameter form(s) by means of a scatter plot. If necessary, choosing transformation(s) and again checking until reaching satisfying distribution(s).
- d) Starting and running the regression program; calculating Difficulty or Keeping, respectively, subsequently checking the result plot regarding:
 - d1) Approximately regular frequency of values along the imaginary line with value 5, i.e. from left to right.
 - d2) Approximately regularly decreasing frequency of values at right angles to the imaginary line with value 5, i.e. towards top and bottom.
 - d3) Values below 2 or above 8 occurring rarely and remaining near these limits.

Checking Difficulty or Keeping values in this way corresponds to using the result plots being shown later on and is the straightforward action if Difficulty and Keeping are being calculated routinely from scatter values, for example by using the software that will be explained in Chap. 15. If this is not the case, a result plot can be produced using the scatter values themselves and can be checked based on appropriately adapted criteria.

- e) In the case that several transformations are possible and approximately equivalent according to c): Calculating several Partial Comparisons of the same goal and choosing the Partial Comparison with the lowest significance level and/or the highest coefficient of determination.

8.5 Realization Probability of Project Objectives

Doing an initial comparison, we can make inferences from the scatter value distribution of the descriptive comparison included to the realization probability of

potential subobjectives of the new project. In spite of the projects being similar, we run a considerable risk making this inference, as we did already in doing an initial comparison, because projects are processes determined not by laws of nature, but by human wills; but we want to describe the procedure all the same.

Ideally – but not imperatively for the balance function being correct [38] – the distribution of the scatter values h corresponds to certain statistical regularities called a normal distribution. Its diagram resembles the shape of a bell, like the one shown in Fig. 8.3 in a slightly flattened way.

In this case, we can use tables available from statistics books giving the distribution function of the standard normal distribution [41] to find the probability of realization for certain scatter values, assuming the scatter values are normally distributed.

This probability on the condition of normal distribution can easily be translated into Difficulty S and Keeping E , respectively, of the corresponding target values, and is presented in Fig. 8.5 for some values of these characteristics.

In Fig. 8.5, the realization probability means the probability that the new project will reach at least the given value – i.e., this or an even higher one, – of Difficulty S or Keeping E , respectively. Analogously, this probability holds for the corresponding values of the target variable.

	Difficulty S or Keeping E	Realization probability under normal distribution
Fig. 8.5 Realization probability of certain values of Difficulty S or Keeping E , respectively, from Partial Comparisons, under the condition of normally distributed scatter values	8.0	0.001
	7.5	0.006
	7.0	0.023
	6.5	0.067
	6.0	0.159
	5.5	0.309
	5.2	0.421
	5.0	0.500
	4.8	0.579
	4.5	0.691
	4.0	0.841
	3.5	0.933
	3.0	0.977
	2.5	0.994
2.0	0.999	

The values of Fig. 8.5 are valid for a single target only, i.e. for one Partial Comparison, but not when we are averaging for higher order characteristics. Obvious relationships of targets as well as arbitrarily determined goal weights prevent a simple transfer of these values to higher order characteristics.

Furthermore, we cannot always assume normal distribution of the scatter values h . In a real Partial Comparison, we do not know the distribution function of the

scatter values. This is the reason why I would prefer another way of calculating the realization probability, namely from the empirical characteristics of the comparison concerned:

At first, all the values of a characteristic of the comparison concerned will be sorted according to size, hereby giving a rank to every value: The highest value gets rank 1, the second highest rank 2, the third rank 3, and so on.

Dividing each one of these ranks by the number of ranks, which we want to call n' because of its almost corresponding to the number of projects covered by the comparison, we get a “relative rank” between 0 and 1: The relative rank of the highest characteristic value is nearly 0, the relative rank of the lowest characteristic value has to be 1, as the last rank is equal to the number n' of ranks.

This relative rank almost is the realization probability we are looking for. Only a tiny correction is missing:

A probability of 1 (i.e., 100% probability) corresponds to complete certainty, i.e. any characteristic value lower than the one we got in our comparison should be impossible. Obviously, this is not the case.

For this reason, we will not divide the ranks by n' , but by $n'+1$; then the relative rank of the lowest characteristic value is near 1, but not equal to 1. The result of this division will be called empirical realization probability of a characteristic value (Rea). The same procedure holds for higher order characteristics of a Total Comparison.

$$\text{Empirical realization probability of a characteristic value} \quad \text{Rea} = \frac{\text{rank}}{n' + 1} .$$

In an initial comparison, the envisaged characteristic value of the new project gets a rank, too, which has to be included in the number n' of ranks. So, n' is the number n of projects included in the descriptive type 2 comparison plus 1. In a final comparison, $n' = n$.

All the same, we have to be aware of the fact that the Rea loses relevance if it is based on few or irregularly distributed characteristic values. In these cases, the relationship between Rea values and characteristic values is too weak.

In connection with the realization probability, we want to mention a side effect of project comparisons, using once more the normal distribution: Fig. 8.5 shows that the realization probability on the condition of normally distributed scatter values also has values of nearly 0 or 1, given Difficulty or Keeping values of 2 or 8, respectively. Beyond these values, almost no realizations can be expected, a fact that justifies the term outlier mentioned earlier.

On a finite scale, however, the bell-shaped normal distribution never reaches the probability values 0 or 1 but only approaches these limits asymptotically. Beyond the characteristic values 2 and 8, even beyond the values 0 and 10, there still remains a tiny probability for realizations. These cases should occur so rarely that they do not force us to change the scale constant 5 in the definition of Difficulty and Keeping, which results in a scale that is easily manageable.

Actually, on investigating project properties, we find Difficulty or Keeping values beyond 0 or 10 not as rarely as this remaining probability would imply. Presumably,

this is not caused by a missing normal distribution of the scatter values, as this is not mandatory for a correct regression analysis.

Rather, the causes might be too low project similarity, insufficient transformation, data errors, or violation of regression conditions. Therefore, such Partial Comparisons should be thoroughly checked and possibly improved.

8.6 Parametric Project Model

Some notes on the parametric method for readers interested in project theory:

With the symbol k introduced in Sect. 8.1 for enumerating target variables, we can express all decomposition equations for descriptive Total Comparisons of type 1 to type 6 in one single formula.

In this formula, we want to characterize initial and final values by the Greek letters alpha (α , from German “Anfang”) and epsilon (ϵ , from German “Ende”), respectively, or generally by the letter l for any process related project status that could be an intermediate status as well.

Let us assume a constant order k and number z of targets in all of the Total Comparisons. If we do not want to specify whether every decomposition equation contains the same order j and number p of influences, we add the indices k and l to j and p in the equation.

Finally, for the sake of completeness, we indicate the label m of Total Comparisons, introduced in Sect. 6.5 and used for identification of successive values and characteristics. Inside the formula, it is functionally irrelevant; together with the other indices, however, it serves to show which types of data can be expected for the different variables.

Then,

$$y_{ik/lm} = a_{k/lm} + \sum_{j=1}^{p_{k/lm}} (b_{jk/lm} \times x_{ijk/lm}) + h_{ik/lm} ,$$

where

- $i = 1, \dots, n$ project number,
- $j = 1, \dots, p_{k/lm}$ influence number inside one Partial Comparison,
- $k = 1, \dots, z$ target number inside one Partial Comparison,
- $l = \alpha, \dots, \epsilon$ initial, final, or intermediate values,
- $m = 1, 2, 3, \dots$ Total Comparison label,

for example

$x_{ijk\alpha m}$ = initial model values of parameters and quasi-parameters,
possibly also of (initial) Difficulty,

$x_{ijk\epsilon m}$ = final model values of parameters and quasi-parameters
except from Difficulty.

If apart from initial and final values, intermediate values of project data have been collected, too, we will get further symbols for process status aside from α and ϵ . Note that the l value for one, several, or all influence variables may differ from those of the other terms of the same decomposition equation; this follows from the different comparison types. We will demonstrate an example in Sect. 8.7.

For the moment thinking about only one isolated project P instead of comparing several projects, we can leave out the symbols i and m . The sets of target values y_{kl} , the corresponding goal weights W_{kl} , and the values of the selected influences x_{jkl} form an analytical model P' of project P , i.e. of its goal values Y_{kl} , goal weights W_{kl} , and parameter values X_{jkl} .

Put into words, this project model consists of process related and possibly transformed values of selected parameters and weighted goals. The model value of a goal consists of a sum of weighted model values of parameters, a block value, and a scatter value.

For a more detailed mathematical description, we use the braces $\{ \}$ as the symbol for sets, the symbol \cup for the union of sets, the comma $(,)$ for listing related elements, and the separator $|$ of set theory [50]. Any other symbols have the same meaning as in the formula above.

$$P' = \{x_{jkl}\} \cup \{(y_{kl}, W_{kl}) \mid y_{kl} = a_{kl} + \sum_{j=1}^{P_{kl}} (b_{jkl} \times x_{jkl}) + h_{kl}\}$$

This analytical or Parametric Project Model not only lies at the base of defining Difficulty, Keeping, and Goodness. It is valid as well for unique projects, which are incomparable to others, although a , b , and h here cannot be quantified empirically. With $j = 0$, we get the non-parametric case of Sect. 3.9.

The model also allows advanced project considerations, potentially including satisfaction, form of project management, etc., as mentioned in Sect. 5.3. Inverting the transformations made for linearization, if necessary, we calculate project values out of model values.

This relationship between model and project values can be expressed analytically:

$$x = f_1(X) \text{ and/or } y = f_2(Y),$$

the transformation functions being any that ensure linearity between x and y . The possible case of X and Y already having a linear relationship is included in the quasi-transformations

$$f_1: x = X \quad \text{and} \quad f_2: y = Y.$$

8.7 Difficulty as a Quasi-Parameter

As mentioned in the preceding section, the l value of influence variables can differ from that of other terms in the equation. For comparison types 2, 3, 5, and 6, the l value with x is different from that with $a, b, h,$ and y , whereas for type 5, it is even different from that of other x variables.

For better understanding, let us analytically consider comparison types 5 and 6, where Difficulty is included as an influence. For this inclusion of Difficulty, no final Difficulty forms are suitable because of the successive Partial Comparisons, except in some special cases mentioned in Sect. 6.2. Here, we want to restrict ourselves to initial Difficulty forms only.

There are as many such quasi-parameters “initial Difficulty” as there are initial Difficulty characteristics, i.e. seven in the case of the Basic Objective Structure. In this context, we will call them

$$S_{k'\alpha} ,$$

and the influence variables derived from them, according to the terminology introduced in Sects. 8.1 and 8.2

$$S_{k'\alpha}' .$$

Numbers of Base-Targets may appear as k' , but not numbers of Check-Targets, and additionally imaginary numbers of higher-order Difficulty characteristics; this is what the apostrophe of the symbol k' implies. With the Basic Objective Structure, k' therefore stands for the subobjective symbols A, K, L, O, P, Q, and T.

Because of the complex interrelations of a project, any one of these Difficulty characteristics may influence targets of type 5 and type 6 Partial Comparisons. To keep our example lean, we want to select only one of these influences and name this

$$S_{k''\alpha}' .$$

Let us further suppose that order j and number p of influence variables are constant throughout these Partial Comparisons and that the influence variable Difficulty has the sequential number $j = p$ for each one of the Partial Comparisons concerned. The preceding numbers $j = 1$ up to $j = p - 1$ will be assigned to the other influence variables; the label m may be left out.

For comparison type 5, y_{ike} is

$$y_{ike} = a_{ke} + \sum_{j=1}^{p-1} (b_{jke} \times x_{ijke}) + b_{pke} \times x_{ipk\alpha} + h_{ike} ,$$

the Difficulty influence values being $x_{ipk\alpha} = S_{ik''\alpha}'$,

where

$i = 1, \dots, n$ project number,

$j = 1, \dots, p$ influence number in the final Partial Comparisons ($p =$ number of the Difficulty influence),

$k = 1, \dots, z$ target number in the initial and final Total Comparison.

As the influence variable $S_{jk'\alpha}$ influences the final value $y_{ik\epsilon}$, its influence weight carries the symbol ϵ for final values, although the Difficulty itself is an initial value. Substituting $x_{ijk\epsilon}$ by $x_{ijk\alpha}$, we get comparison type 6; there, and also with comparison type 2, influence weights for final values may occur with influence values from initial values.

The purpose of this section was to show this. The detailed analytical presentation given in Sects. 8.6 and 8.7 is meant for interested readers. We can use the project model and the different comparison types very well without analytical formulae.

8.8 The Systematics of Terminology

Besides the in-comparison selection-oriented numberings j and k , with the symbols X and Y we may again use—as with the project symbol P —fixed documentation numbers d that can reflect the systematics of data keeping and appear in the evaluations later on. As these documentation numbers never stand without the preceding main symbol P , X , or Y , and as they are written with three digits and not as a subscript, i.e. in a different way from j and k , there is no danger of confusion.

In the practical cases of the present work, initial and final values have got different documentation numbers. Therefore, an additional symbol indicating the reference date can be omitted.

Using the symbols S , W , X , and Y in balance functions effectively shows where the data come from. Unfortunately, this transparency holds not for all details.

For example, our mathematical symbol x not only represents influence values from parameters X , but also influence values from quasi-parameters S (Difficulty), W (goal weight), and Y (goal); however, not even two Y variables occurring in one balance function will lead to confusion, because their numbers d will be different.

If you want to avoid these little conflicts, you may additionally name the Difficulty and goal weight variables as X variables when using them as influences, although this may be cumbersome.

Alternatively, instead of X or Y , you may choose a specific or neutral term for all project values kept, which according to the purpose of an evaluation can take the role of X or Y , respectively. One possibility that would not collide with other symbols presented in this work would be substituting X_d and Y_d by C_d (C as in “characteristic”). In these cases, however, we lose the partial transparency of terminology.

We will finish Chaps. 6, 7, and 8 listing the most important part of our terminology.

If you want to use more complicated transformations of collected target forms than those given here, enclosing the DP target name in parentheses and adding the balance function symbol $\hat{\ } (hat)$ behind the closing parenthesis might help keeping things clear.

Initial comparison	Math. InitialCo	DP InitialCo
Final comparison	FinalCo	FinalCo
Descriptive type 2 comparison	Type2Co	Type2Co
Cost, price, or working-time index q ($q = 1, 2, 3, \dots$)	I_q	Iq
Influence variable values (model values)	x	x
Collected form j or d , resp., of project values of parameters ($j =$ sequential number of influences of a Partial Comparison; here e.g. X_1, X_2, X_3 etc.;; $d =$ sequential number of the chronological or technical order of the collected forms in files, e.g. X001, X002, X003 etc.)	X_j	Xd
Unspecified influence variable j or d , respectively	X_j'	Xd'
X_j or Xd , respectively, to the power of r	X_j^r	Xd^{**r}
Reciprocal of X_j or Xd , respectively	$1/X_j$	$1/Xd$
Natural logarithm	\ln	\ln
Exponential function with base e	\exp	\exp
Square root	$\sqrt{\quad}$	sqrt
Multiplication sign	\times	$*$
Block value of a Partial Comparison (y-axis intercept)	a	a
Influence weight (regression coefficient) of influence variables in simple regression	b	b
Influence weight (regression coefficient) of influence variables in multiple regression	b_j	b_j
Target variable values (model values)	y	y
Collected form k or d , respectively, of project values of goals ($k =$ sequential number of targets of a Total Comparison; here e.g. Y_1, Y_2, Y_3 etc. $d =$ sequential number of the chronological or technical order of the collected forms in files, e.g. Y001, Y002, Y003 etc.)	Y_k	Yd
Unspecified target variable k or d , respectively	Y_k'	Yd'
Balance function of target y_k or Yd , respectively	\hat{y}_k	Yd^\wedge
Balance function of target $y_k = \ln(Y_k)$ or $\ln(Yd)$, respectively	\hat{y}_k $y = \ln Y$	$\ln Yd^\wedge$
Balance function of target $y_k = \sqrt{Y_k}$ or $\text{sqrt}(Yd)$, respectively	\hat{y}_k $y = \sqrt{Y}$	$\text{sqrt} Yd^\wedge$
Label of Total Comparisons	m	m
Number of projects of a Partial Comparison	n	n
Number of influence variables of a Partial Comparison	p	p
Number of target variables of a Total Comparison	z	z
Empirical realization probability	Rea	Rea

In the remaining parts of this work, we want to present projects that have actually been realized, and their authentic variable values. In doing so, we will mainly use the DP notation instead of the mathematical one. Of course, the calculation rule [51] that power or square root calculation precedes any multiplication or division whenever those operations meet is valid.

Part II

Application

Chapter 9

177 Projects as an Example

9.1 Contents and Settings

For the evaluations to follow, the material consists of projects from precision engineering product development for mass-production in the years from 1961 to 1983 at the Munich site of Agfa-Gevaert.

Agfa-Gevaert emerged in 1964 out of the German Agfa AG and the Belgian Gevaert NV and, operating world-wide, then had about 30,000 employees and three main sites at Leverkusen, Mortsel (Antwerp), and Munich. Development and production were divided:

In Leverkusen, they developed and produced photographic films and papers for general use, in Mortsel for special use, e.g. medicine and print. The Munich site was supposed to produce the corresponding equipment, i.e. for recording, processing and reproducing photo and film. Every one of these main sites had branches at other locations.

The equipment developed and produced at the Munich site and its branches consisted of mechanical, optical, and electric/electrical components, partly metallic, partly made of chemical material. Some of them contained complicated controlling systems with sensors, light sensitive elements, photographic lenses, later on also data processing elements.

Around 10% of the staff there (a total of about 6,000 employees) belonged to development, the others mainly to production, organized in three departments: workflow organization, manufacture, and customer service. Workflow organization worked on construction and purchase of production tools for fabrication and assembly of parts.

The site had its own purchasing department, human resources department, and some administration, although main administration and sales department were seated at Leverkusen and Mortsel, respectively. Production comprised several hundred products at the same time.

9.2 Product Range

In spite of being similar, the material involves a wide variety of products [58, 100]. It consists of 177 recorded development projects whose objects can be categorized as follows:

Still picture cameras (photographical cameras)	55	projects
Projection equipment and 8 mm film cameras	27	projects
Laboratory equipment for film developing	21	projects
Printer for making paper copies from exposed films	22	projects
Equipment for mechanical handling of exposed films, copies, and slides, e.g., packaging	10	projects
Micro(film) documentation equipment	18	projects
Photocopying machines	5	projects
Graphical equipment for printing	12	projects
X-ray equipment	7	projects

Whereas all readers certainly are familiar with cameras and their prices, laboratory equipment and printers are huge and heavy investment objects for picture handling industries. Their prices, then calculated in DM (“Deutsche Mark”), can be as high as several hundred thousand dollars. Of course, these differences also have an impact on the corresponding realization of a project.

Production costs of the products listed span more than four orders of magnitude. The objects were partially fabricated in limited-lot production, partially in large-scale production; the numbers of items planned span more than five orders of magnitude.

9.3 Project Realization and Organization

9.3.1 Phases

The projects to be compared were divided into four phases for scheduling and project comparisons:

- Conceptual phase
- Development phase
- Production engineering phase
- Production start-up

Production start-up was a sub-phase of production. The production phase, which is part of the product life cycle, is finished only when the production is terminated, whereas the development project is finished when production has been started up.

The project phases were defined as follows:

Conceptual Phase:

The start of the conceptual phase was the date of writing down the product idea for the first time, e.g. in protocols of product planning conferences, being discussed continually and leading to product definition and a developing assignment.

The point of the term “being discussed continually” is that some product proposals, having initially been declined – maybe even several times – for technical or economical reasons, may have been renewed later under different circumstances. In this case, not the earlier declined proposal, but the latest reactivation of the product idea leading directly to the development assignment was taken as the start of the conceptual phase. Thus, the start date of the conceptual phase was determined only after authorizing the development.

Development Phase:

The development phase started by issuing the development assignment, i.e. when the conceptual phase had been finished, and ended when the set of drawings of the future product was completed, checked, cleared by the development department, and passed on by the drawings office to enable production engineering.

Production Engineering Phase:

Production engineering automatically started when the development phase had been finished. The production engineering departments were working at time-critical drawings already during the development phase.

The production engineering phase was finished with the end of the preparations for the pilot series. This date resulted from the start date for pilot production decided by the production department. The term pilot production will be explained in the next paragraph.

Production Start-Up:

Production start-up started by beginning pilot production in the assembly department. The pilot series was a comparatively small first series of the new product. It served for instructing the assembly staff and for testing the first parts fabricated in the production department and the assembly devices.

Having finished the pilot series, assembly performance was being increased gradually, which was called series start-up. Series start-up, production start-up, and project were finished at the same time, when the planned daily or monthly number of items was being assembled, indicated by the number of finished products sent into store.

Note:

The initial project data of the present work are meant to represent the state of knowledge recorded when starting the development phase. Duration and costs of the conceptual phase are included in project duration and project costs, respectively.

Analogously, the final data mainly correspond to the state of knowledge when terminating the project. Only final quality data sometimes have been collected about half a year later, insofar as actual and not supposed reclamation rates were concerned.

9.3.2 Project Features

For the projects presented here, important interconnections and dependencies existed between development, production tools, and production departments (Fig. 9.1). The production tools department was in charge of constructing and purchasing the equipment, as mentioned before.

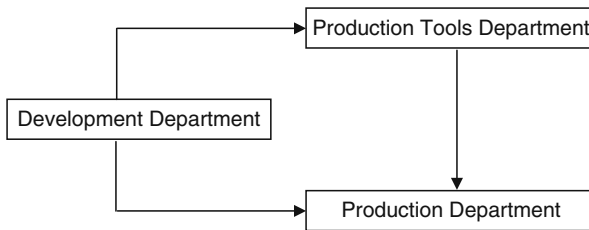


Fig. 9.1 Important interconnections during a project

These dependencies are inevitable and typical for this type of development projects. Supplying the production tools, often an expensive and drawn-out process, as with cutting dies, compression molds, plastics injection molding equipment, and assembly tools for series production, relies largely on quality and promptness of development work.

Production, on the other hand, depends on quality and punctuality of supplying production tools, as well as on immediate information and support by the development department during start-up.

Another important feature of such projects is the product launch. Only partially did the launching date reflect the end of the project.

Important factors for setting a launching date were: firstly, an appropriate occasion stimulating sales, like a Photokina fair in Cologne or Christmas season coming up, secondly, the possibility of satisfying the starting demand by sufficient delivery, and thirdly, strategical advantage over competitors.

The launch date mostly was an important milestone of project realization; often it was determined already in the project definition and controlled with an attention similar to that used with the project finish itself.

9.3.3 Project Management

The projects compared, called starts of production (German “Neuanläufe”), fell in a phase of long-term changing, shifting influence from construction departments, then dominating development, to physics/electronics development departments that earlier only held secondary functions. Simultaneously, production changed from optical and fine mechanical work, done mostly by experienced foremen, to a technologically oriented engineering task.

Up to the sixties, starts of production were thought of as having three distinct parts, as shown in Fig. 9.1. Each part stood on its own concerning planning and responsibility, interaction was by more or less formally handing over sets of drawings, prototypes, or production tools. Formal – even less continuous – project management was unknown, present only in the motivation for success common to all persons involved.

Introduction of plastics into precision engineering, progress in electronics, increasingly complex products and production methods, increasing production numbers, and, last but not least, heavy competition involving deadline and cost pressure all led to integration of tasks. This effect as well as branch-wide trends resulted in changes of organization.

Among the changes involved were a main drawings office, microfilming and network planning technique for the development department, pooling of workflow organization tasks, standardization of materials, production tools, and parts, and creating systematical management job descriptions. At the same time, possibilities for technical/scientific data processing increased, though only in the closed data processing center with batch jobs by punch cards.

In 1972, centralized scheduling of starts of production was started [85]. In the beginning of 1973, formal project management with matrix organization was introduced for developing laboratory equipment, limited to in-house development tasks [29, 100]. These steps manifested project management at the site, although rarely a project manager was continuously responsible for development, production tools, and production.

Bonding the whole process, now interdisciplinary network planning was done and controlled by central staff and contained the above explained phases and controlling up to reaching the full monthly production. Also some projects run not or not completely at the site but at branches or suppliers were monitored in this way.

Towards the end of the seventies, every start of production had a project manager for development and a product officer for production appointed that worked on solutions jointly and early in the process, partly together with specialists of workflow organization.

Chapter 10

Collecting, Keeping, and Processing Data

10.1 Origin

In 1969, I was asked to standardize network planning, in 1972, to build and head the central scheduling of the starts of production at the site.

Since 1965, I had been experimenting with network planning in development and production and recognized its benefits, but also its limits. Particularly, objective measures for the degree of difficulty of projects were missing. Also, we could not determine whether project duration and costs or other important project features were being improved by learning from previous projects.

Aside from attending to routine business, I thought about criteria for the missing project measures, referring myself to project data collected since 1965. I could not find any information on this point with experts, nor in technical literature.

Trying several considerations and calculations with endogenous methods, I always came upon a dead end – inevitably, as I know today. Finally, I came up with an exogenous parametric method, comprising many projects and all their subobjectives, because of their being closely intertwined. In 1968, during an in-house presentation, I had drawn a first small parametric comparison between projects.

Regression analysis had been used since 1971, primarily for production controlling. In 1974/1975 [87], a survey produced a modal parameter “relative degree of scheduling” (in German: “relativer Aufgliederungsgrad”) for project analyses.

About the same time, we intensified collecting internal project data, as far back as possible and in a standardized fashion, to get a relevant data pool of terminated projects. Additionally, in this manner, we got comparative material from the period before central scheduling had been introduced.

I felt supported by first reports about parametric cost and effort estimation in USA [52, 60], as well as hearing about 1965 lecture notes from IBM [57], recommending the use of regression analysis for general company investigations.

In 1983, the project data collection comprised the 177 projects mentioned above and a volume of about 35,000 project data. From that year on, I started working on a freelance basis. I could continue using the collected data, which are the basis of the present evaluations.

10.2 The Concept of Collected Variables

10.2.1 Overview

In 1962, the company had introduced a working-day calendar to facilitate production planning. Numbering all site-wide working-days from 1 to 999, it was based on a five-day week excluding holidays and annual closing times. Following day 999, there was a day 0 followed by another day 1.

For the purpose of collecting data, this working-day calendar, being in use anyway, was extended in 1975 by adding 1,000 days into the past and expanding its range to 9,999 working-days using an additional digit. Now, day 1 of this project calendar was 1957-10-11, day 9,999 1998-6-3. Another digit would have provided further expansion into the future.

This ensured that dates were being given in standardized and calculable units, as well as periods in numbers of working-days. Equally obvious was the use of DM (“Deutsche Mark”) or TDM (“Tausend Deutsche Mark”, 1,000 DM) as financial units.

Projects were being filed in the data collection, which was called file of projects, using the letter P and the documentation number d that corresponded to the order of finishing the projects. Likewise, the symbols X and Y were being used for collected forms of project values, but with a meaning slightly different from that in the present work:

X together with documentation number d indicated variables taken from schedules or other authentic sources, e.g. calculations, quality plans, conference notes, or determined particularly for the purpose of doing project comparisons. The variables in this category were regarded as primary variables.

Y together with documentation number d indicated collected forms, e.g., duration of project phases, that had been derived from primary variables, e.g., start dates of project phases. These values were calculated, not taken directly from the sources mentioned; nevertheless, they were used so often that it seemed appropriate to give them symbols of their own.

The differentiation between primary and derived variables was due to the collection effort. The system was aimed at collecting as few variables as possible by cost-intensive personal notes, but to choose the data in such a way as to enable easy calculation of many variables important in comparing projects.

Furthermore, recording errors were to be expected, and thus to be looked for, only with primary variables, whereas with derived variables, in the case of errors, only the general calculation method could be wrong and had to be checked. In the sense of the present work, however, both of these categories of variables were collected forms of project values.

As we have seen, goals and parameters can have identical symbols in this system of X and Y. All the same, the balance functions to be shown later on correspond to the terminology introduced in Chap. 8 and used throughout this work, because, almost invariably, the goal forms appearing there were Y variables, the parameter

forms X variables. Only one parameter form had to be renamed for use in balance functions.

Apart from the variables listed so far, activity data out of the standardized central schedules had been collected in a file of activities to be used for future scheduling. Later on, these data were incorporated into the system of X and Y variables, adding one letter, so that goals and parameters for project comparisons could also be taken from this detailed collection of project data concerning scheduling and running of projects.

To adjust costs and prices for inflation influences, the indices described in Chap. 7 were collected and filed in a separate index file. Temporary data, i.e., data that were not permanently defined, were indicated by Z and a numerical suffix; often these were tentative precursors for an X or Y variable permanently defined later on.

10.2.2 Details

Figure 10.1 demonstrates examples of primary data. Incomplete series with missing values were indicated. As far as acceptable concerning exactness, in a duplicate of these series, the missing values were substituted by reasonable values from other variables and the new series indicated by an additional suffix, e.g. X005 and X005A. Such additional suffixes were used also in other connections.

X004	Initial start of development phase, incomplete
X004A	Initial start of development phase, missing values completed by X009 values
X005	Initial start of production engineering phase, incomplete
X005A	Initial start of production engineering phase, missing values completed by X010 values
X006	Initial start of production phase
X007	Initial start of production of full daily/monthly number of items
X008	Final start of conceptual phase
X009	Final start of development phase
X010	Final start of production engineering phase
X011	Final start of production phase
X012	Final start of production of full daily/monthly number of items
X013	Initial development costs in TDM, nominal
X014	Initial production tool costs in TDM, nominal
X015	Initial additional production costs in TDM, nominal
X016	Initial net production costs in DM, nominal
X017	Initial project order value in TDM, nominal
X018A	Cost index of the initial cost estimations of a project
X019	Final development costs in TDM, nominal
X020	Final production tool costs in TDM, nominal
X021	Final additional production costs in TDM, nominal
X022	Final net production costs in DM, nominal
X023	Final project order value in TDM, nominal
X024	Cost index in the year of project finish

Fig. 10.1 Examples of primary variables (different use of X)

Figure 10.2 shows a selection of collected forms derived from the primary variables in Fig. 10.1. The mathematical definitions are given for the first three variables to exemplify the derivation.

Y014	Final project duration, nominal	$(X012 - X008)$
Y015	Initial project costs in TDM, nominal	$(X013 + X014 + X015)$
Y016	Final project costs in TDM, nominal	$(X019 + X020 + X021)$
Y017	Initial development costs in TDM, index corrected	
Y018	Initial production tool costs in TDM, index corrected	
Y019	Initial additional production costs in TDM, index corrected	
Y020	Initial project costs in TDM, index corrected	
Y021	Initial net production costs in DM, index corrected	
Y022	Initial order value in TDM, index corrected	
Y023	Final development costs in TDM, index corrected	
Y024	Final production tool costs in TDM, index corrected	
Y025	Final additional production costs in TDM, index corrected	
Y026	Final project costs in TDM, index corrected	
Y027	Final net production costs in DM, index corrected	
Y028	Final order value in TDM, index corrected	

Fig. 10.2 Examples of derived variables (different use of Y)

Also with activity data, X and Y variables were distinguished in the sense of primary and derived variables, respectively. Further characterization consisted in a letter for a specific variable type and the activity number out of the standardized central schedule (Fig. 10.3). In Sect. 13.5, we will discuss these variables.

XK2862	Final start date of pilot production
XL2862	Final finish date of pilot production
YB2786	Final duration of tools supply
YB2862	Final duration of pilot production
YE2862	Relative final start date of pilot production in proportion to project duration
YF2862	Relative final finish date of pilot production in proportion to project duration

Fig. 10.3 Examples of activity variables (different use of X and Y)

The index values used in project correction for cost, price, and working-time – index 1 or 2, depending on the object – were taken from the index listings shown in Fig. 10.4 and were recorded as separate collected forms, e.g. X018A.

The original series of the indices shown in Fig. 10.4 were taken from the “Statistisches Bundesamt” and “Institut fuer Arbeitsmarkt- und Berufsforschung” publications listed in the bibliography. Concatenation, where necessary, was carried out according to Chap. 7.

Variables X018A and X024 were meant for correction for currency depreciation of project costs that were predominantly due to human resources costs; therefore, average salaries were chosen as a measure. In case of doubt, repeated project comparisons using other indices had been planned.

1. Concatenated index of producer prices for industrial products, category of fine mechanical and optical products and timepieces [71]; base year: 1970

1960	76	1966	90	1972	111	1978	147
1961	79	1967	91	1973	115	1979	151
1962	83	1968	91	1974	124	1980	156
1963	83	1969	93	1975	134	1981	161
1964	85	1970	100	1976	139	1982	168
1965	87	1971	107	1977	143	1983	173

2. Concatenated index of producer prices for industrial products, category of office machines and data processing equipment [71]; base year: 1970

1960	76	1966	90	1972	96	1978	94
1961	79	1967	91	1973	94	1979	86
1962	83	1968	100	1974	96	1980	85
1963	83	1969	101	1975	100	1981	86
1964	85	1970	100	1976	100	1982	88
1965	87	1971	99	1977	97	1983	88

3. Concatenated index of the average gross monthly salary for industry and commerce staff [72]; base year: 1970. Used for variables X018A and X024 of all projects.

1960	49	1966	76	1972	120	1978	190
1961	53	1967	79	1973	132	1979	201
1962	57	1968	82	1974	146	1980	215
1963	61	1969	89	1975	158	1981	226
1964	65	1970	100	1976	168	1982	237
1965	71	1971	110	1977	179	1983	244

4. Index of reciprocal annual working-time, calculated by me from information of the German "Institut fuer Arbeitsmarkt- und Berufsforschung" [47]; base year: 1970. Used for variables X096 and X097 of all projects.

1960	91	1966	97	1972	103	1978	110
1961	92	1967	99	1973	105	1979	111
1962	94	1968	99	1974	106	1980	112
1963	95	1969	99	1975	109	1981	113
1964	95	1970	100	1976	107	1982	113
1965	95	1971	102	1977	108	1983	113

Fig. 10.4 Indices used for price, cost, and working-time correction; the variables X096 and X097 mentioned with index 4 are to be understood the same way as the variables X018A and X024 mentioned with index 3

10.3 Collection Stages and Reference Lists

To be able to improve the planning of new projects by project comparisons we had to collect initial data of any new project at an early stage and to include them in comparison files. Many final data, on the other hand, by their nature only could be collected after having finished the current project.

Inserting project comparisons into the regular planning process thus required stepwise data recording. In the course of time, the following subdivision in four

collection stages was found to be appropriate to have the greatest amount of data available for comparisons at any given time:

Collection stage 1 could be reached already before starting development, assisting project conception. In this case, the data constellation was viewed as being a first draft, having room for improvement. Its extent was fixed on data collecting sheet 1 (Fig. 10.5); the project number was only tentative.

Starting with the moment of arranging a binding project schedule, the polished data of data collecting sheet 1 were fixed as binding initial version of the project.

Erfassungsblatt 1 zur Projektdatetei Prov. Proj.-Nr.: _____

Projektname: _____

Projektkurzbezeichnung: _____ OP-Nr.: _____ Typ-Nr.: _____

Fremdfirma: _____

A-Zielgewichte:	A-Charakteristik:
Projektkosten X70 =	Produktgruppe X25 = X25A =
Projektkostentreue X71 =	Innovationsgrad* X26 = X26A =
Projektdauer X72 =	Fremdanteil X27 = X27A =
Terminstreue X73 =	Auflagehöhe X28 = X28A =
Herstellkosten X74 =	Sachnummernzahl* X29 = X29A =
Herstellkostentreue X75 =	Dringlichkeit* X49 = X49A =
Fehlerquote X76 =	G-Quote* X57 =
Qualitätstreue X77 =	

Termine und Folgegrößen:	Datum	Datum	AT
Jahr des Ist-Projektbeginns		X 1 =	
A-Konzeptbeginn, unv.	X 3 =	} X 3A =	
ersatzweise Ist-Konzeptbeginn,	X 8 =		
A-Entwicklungsbeginn, unv.	X 4 =	} X 4A =	
ersatzweise Ist-Entwicklungsbeginn	X 9 =		
A-Fabr.-Vorbereit.-Beginn, unv.	X 5 =	} X 5A =	
ersatzweise Ist-Fabr.-Vorbereit.-Beginn	X10 =		
A-Fabrikationsbeginn		X 6 =	
A-Beginn der vollen Tages-/Monats-Stückzahl		X 7 =	
A-Zusagetermin der A-ME-Menge (Wunsch)		X65 =	
A-Bereitstellungstermin der A-ME-Menge		X66 =	
A-Markteinführungsmenge (Wunsch)		X66A =	
A-Projekthäufung im Ressort Fototechnik		X51 = X51A =	
A-Projekthäufung in der Produktgruppe		X53 = X53A =	
Relative A-Dauer der zentralen Terminüberwachung (Beginnschätzung X45 pot = nur für X68)		X68 =	
Ist-Tag der A-Kostenschätzungen		X48 =	

Kosten und Folgegrößen:	Kostenindex der A-Kosten-schätzungen
A-Entwicklungskosten TDM X13 =	X18A =
A-Betriebsmittelkosten TDM X14 =	Preisindex im Jahr X1 X31 =
A-PZS-Kosten TDM X15 =	A-Händler-Nettopreis in DM X30 =
A-Netto-Herstellkosten DM X16 =	A-Stückgarantien in DM X55 =
A-Projekt-Auftragswert TDM X17 =	Relativer A-Aufgliederungs-grad (Zv = nur für X69) X69 =

F-Deklinations-Stand der Projektkosten X86 =	Programmversion von REGIE-1: von REGIE-2:
F-Deklinations-Stand der Projektkostentreue X87 =	
F-Deklinations-Stand der Projektdauer X88 =	
F-Deklinations-Stand der Termintreue X89 =	
F-Deklinations-Stand der Herstellkosten X90 =	
F-Deklinations-Stand der Herstellkostentreue X91 =	
F-Deklinations-Stand der Fehlerquote X92 =	
F-Deklinations-Stand der Qualitätstreue X93 =	

09.07.82, 217-was-re, 2660H
Fig. 10.5 Data collecting sheet 1

* Referenzliste

Any changes like schedule revisions or such were differences to the initial data, appearing as final data.

Collection stage 2 was entered after finishing the development stage, collection stage 3 after reaching full daily/monthly production rate (project finish). The corresponding data were collected with a common data collecting sheet "2+3" (Fig. 10.6). As far as personal estimations were required, these were collected during the month following the moment when the corresponding project status had been reached.

Erfassungsblatt 2 + 3 zur Projektdatei Prov. Proj. -Nr.: _____

Projektname: _____

Projektkurzbezeichnung: _____ OP-Nr.: _____ Typ-Nr.: _____

<u>Er fassungsstufe 2</u>	Datum	AT bzw. Wert
Ist-Beginn der Entwicklungsphase	x 9 =	
Ist-Beginn der Fabrikationsvorbereitungsphase	x10 =	
V-Zentralzeitpunkt	x94 =	
(x8 = ; am Tage x10 gültiger		
{ PET 908 : + 1 } = ;		
{ FAT 932 : }		
nur für x94)		

<u>Erfassungsstufe 3</u>	Datum	AT bzw. Wert
Jahr des Ist-Projektendes	x 2 =	
Ist-Produktgruppe	x32 =	
Ist-Sachnummernzahl	x36 =	
Ist-Termtreue	x39 =	
Ist-MIQ der Projektdauer	x62 =	
Ist-Beginn der Fabrikationsphase	x11 =	
Ist-Beginn der Serienfabrikation mit voller Stückzahl	x12 =	
Ist-Beginn der Terminüberwachung	x45 =	
Bingeschränktes (≤x12) Ist-Ende der Terminüberwachung	x46A =	
Ist Ende der Terminüberwachung	x46 =	
"Ist"-Bereitstellungstermin der Markteinführungs- menge (x66A= Stück)	x67 =	
Ist-Innovationsgrad	x33 =	
Ist-Fremdanteil	x34 =	
"Ist"-Auflagehöhe	x35 =	
Ist-Art der Terminüberwachung	x43 =	
Ist-Dringlichkeit	x50 =	

Erfassungsblatt Vorgangsdatei vorhanden
nicht vorhanden

15.02.83, 217-ly-re, 3970H
Fig. 10.6 Data collecting sheet 2+3

Erfassungsblatt 4 zur Projektdatei Prov. Proj. -Nr. : _____

Projektname: _____

Projektkurzbezeichnung: _____ OP-Nr.: _____ Typ-Nr.: _____

_____ Fremdfirma: _____

Ist-Zielgewichte: Projektkosten x78 = Projektkostentreue x79 = Projektdauer x80 = Termintreue x81 = Herstellkosten x82 = Herstellkostentreue x83 = Fehlerquote x84 = Qualitätstreue x85 =	Ist-Projektkostentreue x40 = Ist-Herstellkostentreue x41 = Ist-Qualitätstreue x42 = Ist-Zahl der zentral registrierten Ereignisse x44 = Angemessene Vorgangszahl (Ist) x47 = Ist-MiQ der Projektkosten x61 = Ist-MiQ der Herstellkosten x63 = Ist-MiQ der Fehlerquote x64 =
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Termine und Folgegrößen:

	Datum	AT
Ist-Markteinführungstermin	x67A =	
Ist-Markteinführungsmenge	x67B =	
Ist-Projekthäufung im Ressort Fototechnik	x52 =	
Ist-Projekthäufung in der Produktgruppe	x54 =	

Kosten und Folgegrößen (Stichtag X12 =):

Ist-Entwicklungskosten TDM X19 = Ist-Betriebsmittelkosten TDM X20 = "Ist"-PZS-Kosten TDM X21 = Ist-Netto-Herstellkosten DM X22 = Ist-Projekt-Auftragswert TDM X23 = "Ist"-Weiterentwicklungskosten TDM X95 =	Kostenindex im Jahr x1 X18 = Kostenindex im Jahr x2 X24 = Preisindex im Jahr x2 X38 = Ist-Händler-Nettopreis (DM) X37 = "Ist"-Stückgarantien (DM) X56 =
---	---

G-Quote :

Ist-Stichtag für Ist-G-Quote x58 =	Programmversion
Ist-Garantiesumme für Ist-G-Quote x59 =	von ERGEB :
Ist-Liefermenge für Ist-G-Quote x60 =	

28.03.83, 217-ly-sz, 4335H

Fig. 10.7 Data collecting sheet 4

Some cost and quality data were collected only after actual production costs had been (re)calculated, or after reclamation costs had been observed for about six months, respectively. Data collecting sheet 4 (Fig. 10.7), which contained these data among others, completed the project data. Data collection was closely linked to the general work of central scheduling.

The data collecting sheets shown in Figs. 10.5 through 10.7 are the last versions from 1982 to 1983. Their terminology is not the same as in the present work, and some details are outdated. Please take them as being layout examples, without translation and without complete explanation.

In the next section, we will give a few notes on the DP programs REGIE-1, REGIE-2, and ERGEB mentioned in the data collecting sheets. First, we want to point out a peculiarity of data collection with some of the parameters.

Some parameters, e.g., degree of innovation, were introduced together with systematic data collection and were supposed to subdivide the projects by a personal estimate in three rough categories 1, 2, and 3. Hereby only category 1 and 3 were defined, for example:

- Degree of innovation: 3 = pilot project with extraordinary high proportion of new technology
- 1 = project with extraordinary low proportion of new technology, e.g., re-designing existent products

Category 2 was supposed to contain all other projects. Intermediate values were possible.

To assist estimation, the estimators – senior supervisors of development with several years’ experience in product development – were asked to distribute their values over many projects in such a way as to come up with roughly one fifth of the projects in category 1 and 3, respectively, and three fifths in category 2.

This proposal was approximately based on an assumed normal distribution of estimates; but also significant deviations from this proposal were allowed. Furthermore, all parameters being estimated in new projects were listed in reference lists that could be used as pointers in future estimations.

As an example, Fig. 10.8 shows a reference list of final estimated values of the degree of innovation for printers. This reference list also was used for initial estimations, but it did not contain any initial values to avoid misunderstandings.

Reference list of degree of innovation for printers, status date 1980-11-14 (sorted by final degree of innovation X033, last column)

Project	Product type number	Product description	Year of full production	X033
P061	7328100	Bausatz 110 f. Klstb.-P.	(1972)	1
P063	7416140	Bausatz 110 Frb. Col. N2BH	(1972)	1
P091	7336160	Objektiv-Lgr. f. Col. U+CU	(1974)	1
P152	7560300	Colormator 7560-3	(1978)	1
P147	7564100	Colormator 7560-4	(1977)	1.2
P140	7564	4-Inch-Umbausatz f. Col.	(1977)	1.5
P025	7415	Colormator N2B-S	(1968)	2
P068	7546470	Bausatz 110 Colorm. Aut.1+2	(1973)	2
P090	7512100	Bausatz 110 Colorm. N4B	(1974)	2
P115	7560210	HL-Negativbuehne	(1976)	2
P124	7563300	ADK-Hochl.-Buehne f. 16	(1977)	2
P018	7500100	Colormator N4B	(1966)	3
P030	7541	Colormator N2B Autom.	(1969)	3
P113	7560100	Colormator 7560	(1976)	3
P125	8563100	ADK-Steuer- und Messelem.	(1977)	3
P126	7563200	ADK-Hochl.-Buehne f. 35	(1977)	3
P144	7564113	Lochmarkierer f. Colormator	(1977)	3

Fig. 10.8 Example for a reference list of the degree of innovation

Figure 10.9 shows a reference list of the number of different parts of a product for projection equipment and 8 mm film cameras. The number of different parts was used as an approximate measure of the volume and complexity involved with a product and therefore with the project. It is about the same as the number of parts of a product, but if, for example, a certain type of screw is used at 20 places inside the product, it is counted only once.

Reference list of the number of different parts for projection equipment and 8mm film cameras, status date 1980-11-14 (sorted by final number of different parts X036, last column)

Project	Product type number	Product description	Year of full production	X036
P137	6733	Gucki 135 B	(1977)	13
P135	6740	Agfascop 100	(1977)	16
P141	5257200	Klebepresse N 8 S	(1977)	21
P143	6741	Agfascop 200	(1977)	23
P007	5963	Stehbildwerfer CP 150	(1964)	50
P101	5258222	F 8 S Automatic	(1975)	81
P008	5708	Movector B	(1964)	332
P013	5158	Movex S Automatic	(1966)	335
P049	5706	Movector 888	(1971)	337
P014	5925	Diamator 100	(1966)	352
P015	5922	Diamator 150	(1966)	352
P017	5159	Movex SV Automatic	(1966)	405
P097	5935	Agfacolor Pocket	(1975)	424
P002	5726	Sonector-Phon II	(1963)	451
P027	5145	Microflex Sensor	(1969)	473
P001	5155	Movexoom	(1963)	543
P022	5160	Movexoom S 8	(1967)	668
P108	5176	Movexoom 6 Electronic	(1975)	758
P109	5178	Movexoom 10 Electronic	(1975)	780
P118	5180	Movexoom 10 El. Sound	(1976)	965
P117	5764	Sonector LS	(1976)	1000
P046	5760	Sonector S	(1971)	1587

Fig. 10.9 Example for a reference list of the number of different parts

10.4 File Structure and Evaluation Tools

Corresponding to the progress in data processing, the handwritten project data originally were transferred onto punch cards. Punch cards were the input medium for Partial Comparisons.

For calculating Partial Comparisons, at that time the Siemens statistics program package SIESTA 2, 1974 [68], was used on the central Siemens computer in the data processing center at the site. SIESTA 2 allowed creating rough plots of two variables and frequency distributions.

Starting 1981, additional small programs were being written by the scheduling group for a programmable Hewlett-Packard pocket calculator HP41C to calculate Y data. These are mentioned in Figs. 10.5 and 10.7.

In 1990, I could transfer the data to my Siemens PC-MX2 with operating system SINIX V2.1, dated march 1986. On this machine, I was using the following programs:

Siemens spreadsheet calculation program SIPLAN V2.0, 1989 [69], Siemens statistics program STAT-X V1.0, 1988 [70], Feldle business graphics program IFE-GRAPH V2.8, 1992 [25].

After several studies concerning the process and grouping and re-sorting the data for some years, I found the following working method used also for the present evaluations:

The project data were kept as a spreadsheet with several hundred rows and columns in SIPLAN. For individual evaluations, the corresponding sections of such a spreadsheet were exported from SIPLAN, imported into the statistics program STAT-X and there handled as a STAT-X sheet on its own for Partial Comparisons.

Results of the STAT-X calculations were re-imported to SIPLAN spreadsheets and further developed into new information, e.g., for calculation of higher-level characteristics from the Partial Comparison results.

Finally, the results of these SIPLAN calculations were again exported, read by a self-provided IFE-GRAPH graphics program, and printed as a diagram. Printed output from SIPLAN and STAT-X, as well as word processing, was available.

Given existent gaps in the data, differentiating between collection-oriented and process-oriented data presentation proved to be quite useful. As an example, Fig. 10.10 shows a small segment of a fictitious spreadsheet whose rows are projects and whose columns are variables.

During collecting and checking data, the sequence as shown in Fig. 10.10 is comfortable enough, but not during data processing, because several columns and rows contain irregular data gaps. Figure 10.11 shows a data presentation that is more appropriate for processing.

	Var.1	Var.2	Var.3	Var.4	Var.5	Var.6
P001	–	13	24	3.5	–	4
P002	146	17	19	4.7	11	23
P003	31	8	–	5.6	13	16
P004	85	18	27	1.1	21	4
P005	91	25	14	2.6	–	14

Fig. 10.10 Collection-oriented data presentation

	Var.2	Var.4	Var.6	Var.1	Var.3	Var.5
P002	17	4.7	23	146	19	11
P004	18	1.1	4	85	27	21
P005	25	2.6	14	91	14	–
P003	8	5.6	16	31	–	13
P001	13	3.5	4	–	24	–

Fig. 10.11 Process-oriented data presentation

In the upper left corner of the table in Fig. 10.11, we arranged all projects and variables 2, 4, and 6, as they do not contain any gaps. Furthermore, it is easy to see that for projects P002, P004, P005, and P003 variable 1 is complete, for projects P002, P004, and P005 also variable 3, etc., resulting in delimited areas of data without any gaps as a basis for calculations.

Having data with a sequence as that in Fig. 10.10, we can re-arrange them as in Fig. 10.11, shifting rows and columns containing gaps to the right and lower part of the table, respectively.

Aside from this re-arranging, it has proved useful to execute transformations of collected forms as mentioned in Sect. 8.2 not only when need arises but already have them ready-to-use in the data sheets and spreadsheets, hereby facilitating use and changing of these frequent transformations.

10.5 Data Errors

The usefulness of project comparisons is closely related to the reliability of the data material it is based on. This does not mean the exactness of the fourth or fifth digit of a project value, which often will not be important at all, given the natural uncertainty of the process, but avoiding relevant digressions of the true values that distinguish the projects from each other.

Such digressions might originate in misunderstandings or mistakes writing down data, but also in errors entering, i.e., punching data. For that reason, the hand-written data collecting sheets were checked visually for plausibility, the punch card values were checked individually for matching the data collecting sheets.

There are obvious and inconspicuous data errors. Obvious are, for example, wrong position of numbers in data arrays, decimal points in data columns defined as integer values, blanks in series of digits, or inconsistent scale range. Inconspicuous data errors, however, are values that do not show any obvious fault and so are plausible, but wrong.

I would suppose that over the years, I have found and corrected several hundred obvious errors in the 35,000 basic data. Outlier, multiple re-sorting and checking of the material, as well as occasional program failures helped in discovering the errors. Obvious errors have become rare.

Assuming that the number of inconspicuous errors more or less corresponds to the original number of obvious errors, we may deduce that presumably several hundred inconspicuous data errors still are contained in the material. This assumed rate of remaining errors, i.e., about 1%, will not seriously affect the usefulness of the comparison process itself. But as far as individual projects are concerned, the comparison results may be drastically adulterated, which has to be considered when interpreting the results.

Nevertheless, I did not want to suppress strange evaluation values, e.g. by eliminating the projects concerned, when the original documents could not be checked any more. Eliminating outliers would have contradicted the attempt of developing a generally applicable comparison method. Thus inexplicable outliers, which, however, occurred only very rarely, may be assumed to result from inconspicuous data errors.

Chapter 11

Total Comparison of all 177 Projects

11.1 Purpose

Now we want to look at a Total Comparison of all 177 projects for an example. Various methods of presenting the results to outsiders will mainly follow in the next chapter; first we want to concentrate on goals and parameters, some balance functions, result plots, and statistical issues.

The comparison is a final type 1 comparison, and for the benefit of gaining transparency and clearness, it is based on the same parameters in all Partial Comparisons. Having uniform parameters, however, is not a requisite of Total Comparisons as a rule.

Goals and parameters correspond to simple and obvious comparison possibilities without taking into account possible further enhancement. Only transformations as mentioned in Sect. 8.2 have been used. Some irregularities in the data, caused by special circumstances when collecting them, will be explained as they arise.

11.2 Goals and Goal Weights

The goals correspond to the Basic Objective Structure and have the following forms and names:

Base-Goals	Y026	Final project costs in TDM, index corrected
	Y215	Final project duration in working-days, index corrected
	Y027	Final production costs in DM, index corrected
	Y209	Final defect rate in per mill of the product price, index corrected
Check-Goals	Y186	Project cost FIQ, index corrected
	Y218	Project duration FIQ, index corrected
	Y187	Production cost FIQ, index corrected
	Y210B	Supplemented defect rate FIQ, index corrected

FIQ means the ratio (quotient) of final and initial value

$$FIQ = \frac{\text{Final value}}{\text{Initial value}}$$

of the Base-Goal concerned and is here based on its index corrected values. This is the reason why also with FIQ, we have the characterization “index corrected”. For Y210B, the final/ initial value ratio of defect rate, we have the following peculiarity:

Defect rate, i.e. warranty costs of a product type, expressed in per mill of the product price, had been defined a goal only in 1975 as a measure for product quality in project comparisons. Other quality measures were too much differing in their meanings, as various conferences with quality management had shown.

The final defect rate could be calculated from existent documents also for past projects. But the corresponding estimates from the conceptual stage of these projects, i.e. the initial defect rates, were missing.

As far as the product quality achieved by these projects was known, there lay no sense in retrospectively estimating the initial defect rate. So calculating the defect rate FIQ and the Keeping characteristic was restricted to later projects and was supplemented as far as possible for time series considerations. We will get back to this topic in Sect. 12.5.

All goals chosen had to be minimized during the realization of the projects. This fact standardizes calculating the sign-adjusted scatter values of the Total Comparison and thus prevents calculation errors caused by wrong signs.

Still later than the initial defect rate the first goal weights were determined for individual projects. First only assumptions were used to explore and exemplify the consequences in the calculations, later on the persons in charge were asked for weights.

For this reason, only the latest of the projects collected have “real” goal weights. For the evaluations that will be shown later on, I built approximate means out of these real goal weights estimated by the persons in charge and used them in the place of the assumptions for older projects.

Doing this does not impair the Partial Comparisons of the Total Comparison treated here, as goal weights are not used as influences. Nevertheless, higher-order characteristics are affected, because real weight differences of older projects are missing. Older projects uniformly got the following goal weights:

Final WKS	=	10	Final goal weight of project costs
Final WTS	=	20	Final goal weight of project duration
Final WOS	=	15	Final goal weight of production costs
Final WQS	=	15	Final goal weight of defect rate
Final WKE	=	2	Final goal weight of project cost FIQ
Final WTE	=	4	Final goal weight of project duration FIQ
Final WOE	=	3	Final goal weight of production cost FIQ
Final WQE	=	3	Final goal weight of defect rate FIQ

That the goal weights for Check-Goals are comparatively low is due to the fact that the projects were mainly internal ones, i.e., the main concern lay with the Base-Goals.

The principles of different weighting of Base-Goals and Check-Goals have been outlined in Sects. 2.3.2 and 2.4. Maybe this difference in weight between Base-Goals and Check-Goals actually is astonishingly high and uniform; this is due to uncertainty in the beginning of weighting.

This understandable uncertainty partially resulted in a certain bias in the goal weights or in contradiction to company policy, for example, concerning the weights of quality goals. That defect rate as a quality goal does not show a superior weight in the goal weight list above can be attributed, among other reasons, to some peculiar and subjective weighting that does not represent the company policy in use. Later on we will look at an example.

Also that the same person was working on scheduling and on collecting data for project comparisons could have had an involuntary effect on goal weight estimates by the persons in charge. All these flaws in the examples shown will disappear by establishing goal weights, after an introductory stage, already in the objective definition of projects, thus submitting them to the same fine-tuning process, which can be recommended anyway because of their strategic importance for the running of the project.

The examples of goal weights presented here still come from a tentative and experimental stage. They have been used without alteration to avoid falsification of calculations.

11.3 Parameters

Throughout all Partial Comparisons in this Total Comparison, we find the following parameter forms:

X033	Final degree of innovation
X035	Final number of items planned
X036	Final number of different parts

All three parameters are natural parameters, which is the most obvious type of parameters.

Degree of innovation and number of different parts have already been explained in Sect. 10.3. They influence the goals by investigation effort and natural development and start-up difficulties connected with high degree of innovation or complex products, respectively. The final degree of innovation is a retrospective estimate at the project finish, whereas the final number of different parts was taken from the usual bills of material.

The number of items planned has been mentioned in Sect. 9.2. Its influence on project realization consists in the fact that large numbers of items can be produced more economically than small numbers, but need special project actions. These begin with conception and construction of fabrication and go up to process engineering, assembly and logistics issues.

Number of items planned and number of different parts had been documented at all times for internal reasons, so their collection for use in project comparisons

presented no problems. The three parameter forms used complement each other and are independent from each other.

On second thoughts, however, number of items planned and number of different parts actually are not independent of each other, because big equipment with high numbers of different parts was planned and produced for less customers than, e.g., cameras.

Such inner dependencies in spite of conceptual independence can affect the stability of comparison results [77], which will be treated later on. Anyway, such dependencies cannot be completely avoided.

11.4 Balance Functions and Result Plots

Figures 11.1 through 11.6 demonstrate some typical balance functions and result plots of the eight target variables.

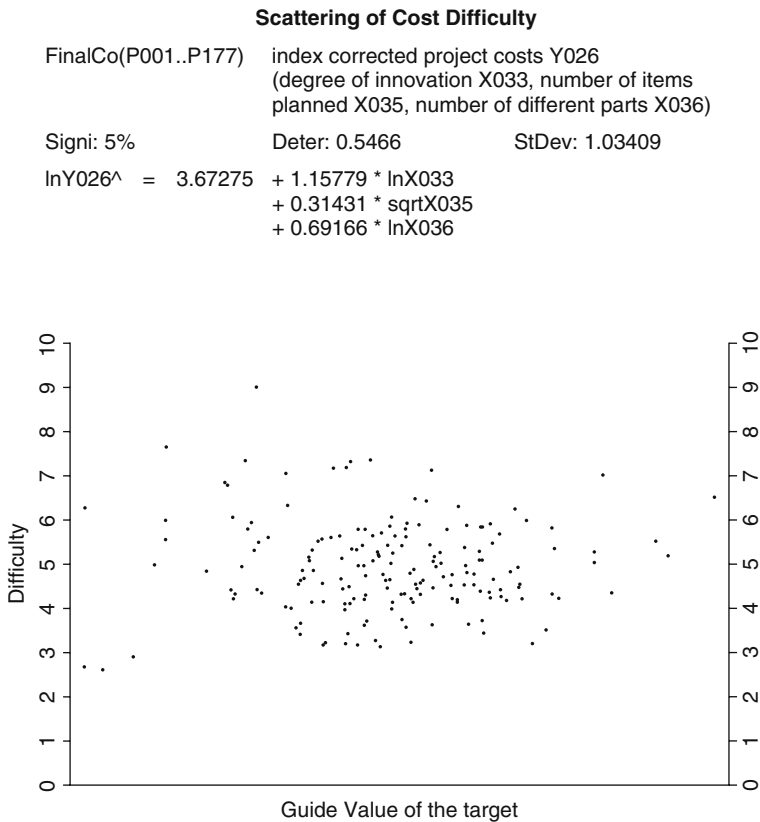


Fig. 11.1 Result plot of the Cost Difficulty of the example

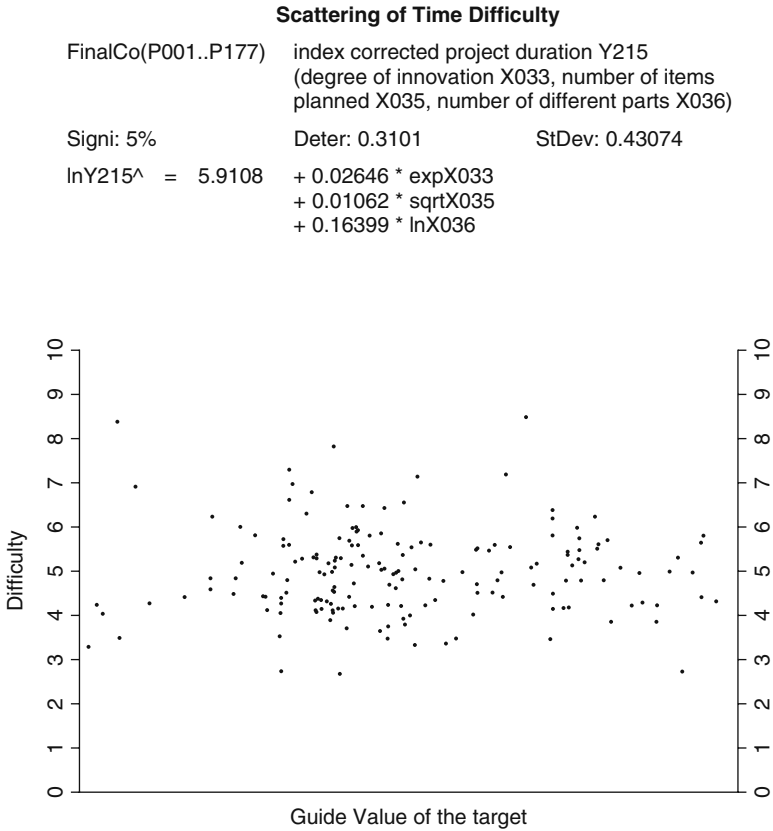


Fig. 11.2 Result plot of the Time Difficulty of the example

In the balance functions shown, the targets always appear as logarithm of the collected form of the goal. With few exemptions, this transformation was the best one also with other Partial Comparisons.

For the purpose of talking about influence variables, we combine the influence variables originating from the collected form of one parameter as introduced in Sect. 8.2 by using the ' sign; for example, X033' stands for the influence variables X033, lnX033, expX033, 1/X033, etc.

In these balance functions, the influence variables X033' (final degree of innovation) and X036' (final number of different parts) always appear to increase the guide values, i.e., the sign of their influence weights causes the guide values to rise if the influence values increase. The same holds for a negative reciprocal, as for influence variable 1/X033 in Fig. 11.4.

This increasing effect on the guide values of project cost, project duration, and production costs by degree of innovation and number of different parts can be easily

Scattering of Object Difficulty

FinalCo(P001..P177) index corrected production costs Y027
 (degree of innovation X033, number of items
 planned X035, number of different parts X036)

Signi: 5% Deter: 0.7714 StDev: 1.19599

$$\ln Y_{027}^{\wedge} = -1.6202 + 0.42988 * X_{033} - 0.02751 * X_{035} + 5.21105 * X_{036}^{*0.2}$$

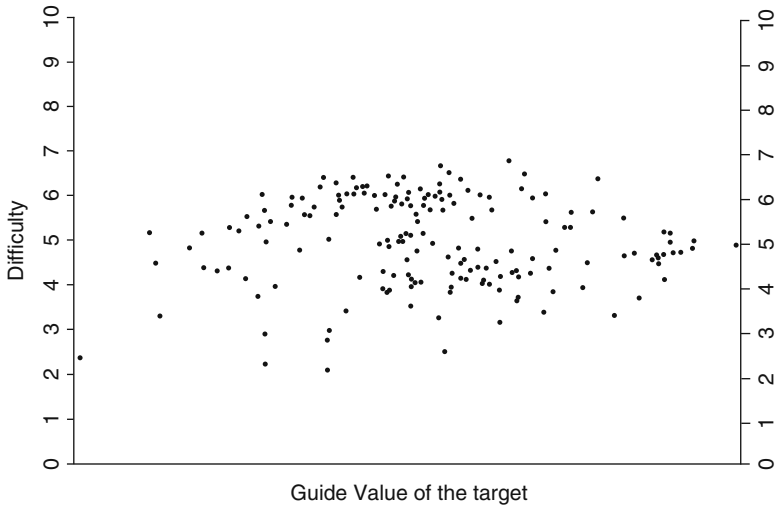


Fig. 11.3 Result plot of the Object Difficulty of the example

understood. It is obvious that the effect on defect rate and FIQs, i.e., excess costs and duration, should be the same.

Influence variable X035' (final number of items planned), on the other hand, has varying effects: it increases guide values of project costs and project duration, but decreases all the other guide values shown. This, too, can be easily understood; decreasing production costs are the aim of planning large numbers of items, and increasing project costs and project duration is the price to be paid for this.

Now we want to look at the result plots.

For many targets, there are several balance functions that may be rather different concerning scattering and the possibility of interpreting parameters or of having consistent parameters throughout the Partial Comparisons. Not always the solutions are completely satisfactory, as Figs. 11.4 and 11.6 may exemplify.

Figure 11.4 and even more Fig. 11.6 reflect the trisection of degree of innovation values. Examples for this parameter have been demonstrated in Fig. 10.8. We can detect serious digressions from the ideal distribution; all the same, we want to keep

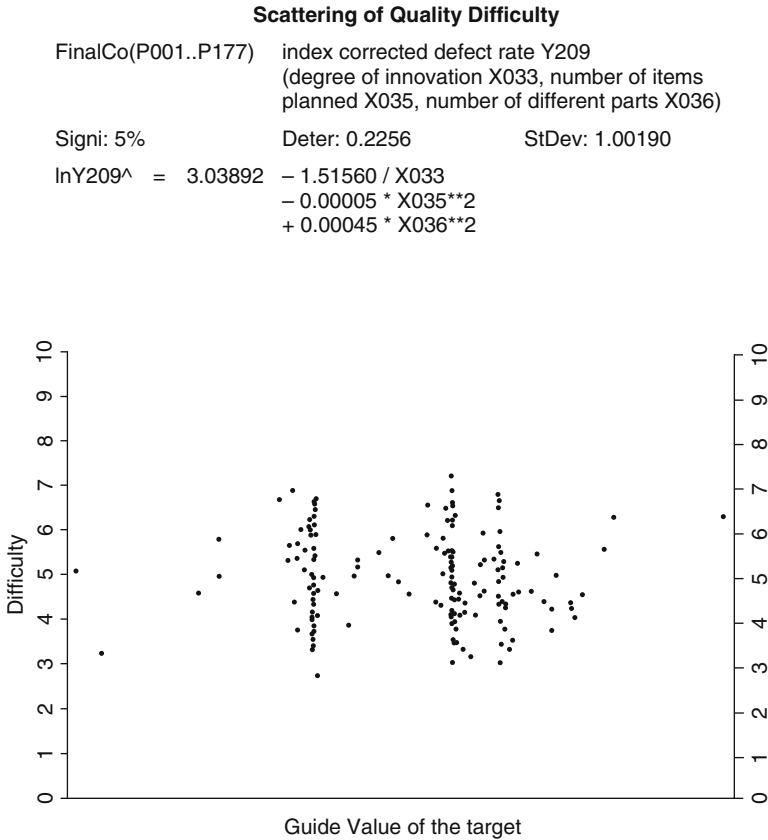


Fig. 11.4 Result plot of the Quality Difficulty of the example

the parameters uniform and so have to tolerate this digression. Setting uniformity aside, the values could be more evenly distributed.

Independent from this issue, the result plots in Figs. 11.1 through 11.6 show some outliers. Exemplarily, we will consider the three outliers that are the most conspicuous.

The first one is the point with a Cost Difficulty of 8.8 in Fig. 11.1. Here a device developed for the German market was submitted for minor modifications for the American market. This correctly defined a project that accounted for only small costs of production tools and neither development costs, nor additional production costs – a truly exceptional situation.

The outlier that comes in second place is the project with a Cost Keeping of 1.2 in Fig. 11.5. Here a by-product of a product family was being developed, constituting an individual project, whose project costs as a whole originally were accounted for with the main product. During the project, allocation of costs to the by-product was decided out of accounting reasons. Initial project costs being zero, the project costs

Scattering of Cost Keeping

FinalCo(P001..P177) index corrected project cost FIQ Y186
 (degree of innovation X033, number of items
 planned X035, number of different parts X036)

Signi: 5% Deter: 0.0736 StDev: 0.83915

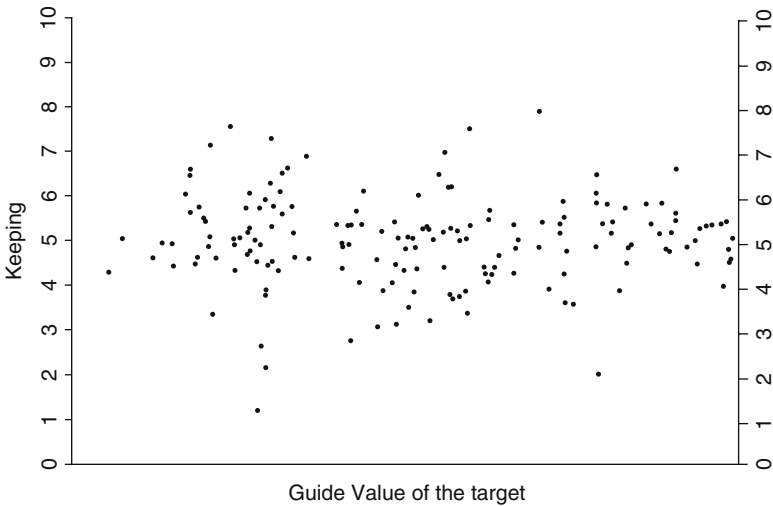
$$\ln Y186^{\wedge} = -0.4856 + 0.24762 * X033 - 0.01907 * \ln X035 + 0.04408 * \ln X036$$


Fig. 11.5 Result plot of the Cost Keeping of the example

FIQ for this project thus went up to infinite. Substituting a large but finite value, as explained for transformations in Sect. 8.2, we get the outlier value $KE = 1.2$.

Only the third strongest outlier is not a formal but a real case: The point with a Time Keeping of 1.3 in Fig. 11.6. Here we have an early project with high degree of innovation, whose duration had been grossly underestimated initially and had to be prolonged over several years.

These examples show that outliers and extreme values in result plots have a certain use: they give hints as to

- limited similarity of projects
- possible data errors
- need for improvement of the balance function (different transformations).

As far as a possible general application of project comparisons is concerned, I think a promising fact is that it is possible to represent all goals of the 177 projects,

Scattering of Time Keeping

FinalCo(P001..P177) index corrected project duration FIQ Y218
 (degree of innovation X033, number of items
 planned X035, number of different parts X036)

Signi: 5% Deter: 0.0772 StDev: 0.30495

$$\ln Y218^{\wedge} = 0.02241 + 0.11327 * X033 + 0.00004 / X035 + 0.01779 * X036^{**0.2}$$

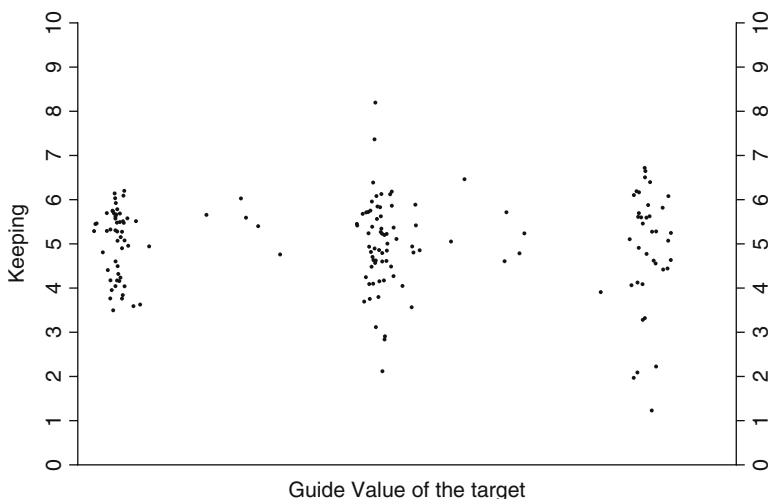


Fig. 11.6 Result plot of the Time Keeping of the example

which even show considerable differences to each other, with only this small number of not very strong outliers that even can be explained to a certain extent. The prerequisite of the projects being similar to each other does not seem to be a major obstacle.

Also a promising fact may be that only three influence variables are sufficient to give a good representation. These results encourage further experimenting on general project comparisons with other types of projects.

The Partial Comparisons presented here, however, have not been checked for linearity between target variable and each individual influence variable. This dissatisfactory omission was due to my limited hardware and software resources. Perhaps some of the transformations would look different had I done a complete linearity evaluation.

The balance functions shown in this context therefore should not be taken as a binding technical proof of certain relationships in the projects concerned. All the same, in my opinion they give an additional insight as illustrations of Project Comparison Technique.

11.5 Statistics Issues

So far, we have not talked about the statistical characteristics of the Partial Comparisons shown because the context did not require this. Descriptive comparisons are independent from these statistical characteristics and only suppose sufficient causality and scattering as long as they do not serve for inferential comparisons, too; that, however, might be expected in most cases, in spite of general reservations in statistics books [80].

Taking into account inferential applications, we can gain important additional information out of statistical characteristics. Therefore, we want to include inferential comparisons in our statistics considerations.

The balance functions of all Partial Comparisons shown as examples reached a significance level of 5% (the meaning of significance levels has been explained in Sect. 8.4). Better significance levels than 5%, e.g., 1%, have not been checked, because the 5% significance level is a default value in the DP program used and conforms to advice in statistics books [42, 79].

The coefficient of determination, however, differs considerably between Partial Comparisons. Looking at Fig. 11.3, we see that 0.7714 or about 77% of the variation in production costs is explained by the influences. With this significance level and coefficient of determination, we might venture a prognosis of production costs by means of the balance function. This procedure is the domain of parametric cost estimation [24] that will be considered in Chap. 14.

The coefficient of determination for the project cost FIQ (Fig. 11.5), however, is only 0.0736, i.e., the balance function represents only about 7% of the influences causing the variation of the project cost FIQ. In spite of the existing balance function and its significance level, statistically the guide values would not be much better than the mean – not taking into account that for Check-Goals the prognosis should be derived from the difference between guide value and initial value of the corresponding Base-Goal, anyway.

But the defect rate in Fig. 11.4 also can be attributed to the influences used with a coefficient of determination of only 23%; here, too, a prognosis would be statistically dubious. Not the existence of a balance function in itself, but its significance and coefficient of determination give statistical coverage to prognoses, and even this does not solve the problem that projects are not subject to physical laws but to willful decisions (cf. Sects. 6.3 and 8.5).

Unfortunately, statistical coverage can not always be attained, with small numbers of projects compared even more rarely. Small numbers of projects in my experience normally resulted in less scattering, but stability of results was reduced, too; few projects being added or taken away would lead to abrupt changes in balance function and statistical characteristics. With small numbers of projects, differences between individual projects prevail.

In Sect. 8.3, we determined the minimal number of projects in a comparison as $p+2$. In my Partial Comparisons, the effects of small numbers of projects – decreasingly – could be seen up to a number of about $p+25$; consequently, Partial

Comparisons with less than about 30 projects would seem doubtful, apart from mere study purposes.

For similar reasons, I would not like to use a greater number of influences in a balance function than about one tenth of the number of projects. This will reduce the inevitable random effects with signs and influence weights of the influence variables.

For comparison results being used not only as a technical planning support but also as a binding evaluation of individual projects, in my opinion they should be based on at least 100 projects and not more than 5 influence variables, thereby keeping a safe distance from statistically doubtful circumstances and offering a combination of parameters that is easy to understand also for non-experts.

In the range of 30–100 similar projects, I would recommend to restrict evaluations to group means of at least 5 projects, as we did, for example, investigating the relative degree of scheduling [87] mentioned before, where results were obtained not by calculation but graphically. Averaging gives certain stability to results.

It should be clear that neither the minimal numbers of 30 or 100 projects, nor the minimal relation of 10 projects per influence are based on a procedural threshold. The procedure gradually causes balance functions to become more stable if more similar projects and fewer influences are used, if causality between parameters and goal is more robust, and if projects are more similar to each other.

Depending on circumstances and purpose of a Partial Comparison, as well as on its data base, stability criteria can thus be chosen quite differently. The numbers mentioned may provide you with a first orientation, allowing for individual changes later on.

In spite of knowing all this, sometimes we will necessarily have to make do with small numbers of projects. In Sect. 1.2, we already pointed out that someone with practical experience in the field will have a look at data from past projects before planning a similar one. He or she will do this even having recourse to only one or two of such projects because the necessity of planning a project does not allow forgoing accessible information.

Early project stages are poor in quantitative information; rough prognoses by inferential comparisons give a quick overview at this stage and are not to be topped, also with regard to calculating several project options. Of course, a thorough and detailed planning will be far better regarding exactness and reliability, but it will take some time which is not always available in business.

Comparisons and even prognoses not covered by good statistical characteristics or stability therefore not always can be discarded. All the more important in these cases are issues like strong similarity of projects, knowledge of the project, experience with comparisons and thoughtfulness of the persons working with the comparison, being aware of questionable procedures, and finally eliminating doubtful results as well as appropriately presenting plausible results. In the next chapter, we will address the issue of presentation.

Part III
Utilization

Chapter 12

Presenting Comparison Results

12.1 General Considerations

Presenting comparison results to outsiders, we have to take into account that persons that are used to handling projects but not project comparisons normally expect more exactness coming from regular detailed planning. They are inclined to overestimate the exactness of project comparison results.

Furthermore, the structural difference between guide values and planned values has to be stressed. Balance functions and guide values are results from investigation or experience observations, whereas planned values are results from decisions and agreements, often even by contract.

Balance functions and guide values more or less lie in the middle between larger and smaller observed values, whereas planned values give a directive that often aims to exclude exactly this middle position; simplified, the directive gives free choice for the person to act up to the planned value, but prohibits to exceed it.

For this reason, guide values usually are not suitable to be proposed as planning values; also, tolerances and non-binding character of guide values may not be appropriate for the often intensive negotiation and evaluation of project subobjectives. Project comparison results should be presented in such a way as to offer their supporting potential without encouraging wrong interpretation.

Aside from this task, we want to distinguish between multi-presentation and individual presentation of results. Multi-presentations give an overview over the whole set of projects included in a comparison, individual presentations only show a single one of these projects. Of course intermediate types may be possible.

One type of multi-presentation has already been used: the result plot. It is the most important type of presentation for doing comparisons. For individual presentation, however, a tabular style may be more suitable; let us have a look at this type.

12.2 Comparison Tables

Figure 12.1 shows an example of a comparison table. It is a final comparison table out of the Total Comparison treated in the previous chapter. This final comparison concerns project P177.

Comparison Results for Project P177 Final Comparison (P001..P177)		(Final Degree of Innovation, Final Number of Different Parts, Final Number of Items Planned)	
		Weight	Value

Sub-Characteristics: not determined			
Basic Characteristics:			
Cost Difficulty	KS	5	4
Cost Keeping	KE	1	4
Time Difficulty	TS	15	5
Time Keeping	TE	3	5
Object Difficulty	OS	10	6
Object Keeping	OE	2	4
Quality Difficulty	QS	5	4
Quality Keeping	QE	1	4

Higher-Order Characteristics (Weighted Means):			Value
Process Difficulty	(from KS and TS)	AS	5
Process Keeping	(from KE and TE)	AE	5
Performance Difficulty	(from OS and QS)	LS	5
Performance Keeping	(from OE and QE)	LE	4
Project Difficulty	(from AS and LS)	PS	5
Project Keeping	(from AE and LE)	PE	4
Cost Goodness	(from KS and KE)	KG	4
Time Goodness	(from TS and TE)	TG	5
Object Goodness	(from OS and OE)	OG	5
Quality Goodness	(from QS and QE)	QG	4
Process Goodness	(from AS and AE)	AG	5
Performance Goodness	(from LS and LE)	LG	5
Project Goodness	(from PS and PE)	PG	5

Scale: 10 = extremely good result, 0 = extremely bad result			
fb177			

Fig. 12.1 Final comparison table

For space saving reasons, the goals are not listed in the table. The table shows the goal weights, all comparison characteristics, and their structural relationships. This simultaneous presentation of individual rating and combined overall rating gives an excellent overview over project realization quality.

The goal weights of the subobjectives of this project correspond to the provisory values explained in Sect. 11.2 only as far as the ratio of Base-Goal and Check-Goal weights is concerned. Apart from this, the goal weights already were tentative estimations by the department in charge of the project concerned; admittedly, the small goal weight of Quality Difficulty was in contradiction to the company's quality rules.

This shows the uncertainty and bias of weighting during the experimental period that has already been mentioned in Sect. 11.2. Anyway, this project recommends itself as an example for several presentation types out of other reasons; the weights here have only formal significance.

The guide values of the project are not contained in the table, which helps avoid the wrong interpretation mentioned in Sect. 12.1. The name fb177 is an example of a label m, introduced in Sect. 6.5; in previous and in future evaluations, authentic as well, in Figs. 11.1 to 11.6, 12.2 to 12.6, and 12.8 to 13.2, the corresponding labels

Comparison Results for Project P177 Proper Initial Comparison (P150..P173) P177		(Initial Degree of Innovation, Initial Number of Different Parts, Initial Number of Items Planned)		
		Weight	Value	Rea
Sub-Characteristics: not determined				
Basic Characteristics:				
Cost Difficulty	KS	5	5	0.5
Cost Keeping	KE	1	5	0.3
Time Difficulty	TS	15	7	< 0.05
Time Keeping	TE	3	5	0.3
Object Difficulty	OS	10	5	0.6
Object Keeping	OE	2	5	0.4
Quality Difficulty	QS	5	4	0.8
Quality Keeping	QE	1	5	0.6
Higher-Order Characteristics (Weighted Means):				
Process Difficulty	(from KS and TS)	AS	6	0.1
Process Keeping	(from KE and TE)	AE	5	0.4
Performance Difficulty	(from OS and QS)	LS	5	0.7
Performance Keeping	(from OE and QE)	LE	5	0.6
Project Difficulty	(from AS and LS)	PS	6	0.2
Project Keeping	(from AE and LE)	PE	5	0.4
Cost Goodness	(from KS and KE)	KG	5	0.5
Time Goodness	(from TS and TE)	TG	6	0.1
Object Goodness	(from OS and OE)	OG	5	0.5
Quality Goodness	(from QS and QE)	QG	4	0.8
Process Goodness	(from AS and AE)	AG	6	0.1
Performance Goodness	(from LS and LE)	LG	5	0.7
Project Goodness	(from PS and PE)	PG	5	0.2
Scale: 10 = extremely difficult requirement, 0 = extremely easy requirement				
Rea: Empirical realization probability of getting the required result or a better one				

Fig. 12.2 Initial comparison table

have been suppressed, as registration of comparisons and evaluations can be done arbitrarily and is without consequences for the comparisons themselves.

Figure 12.2 shows the corresponding initial comparison table. For the underlying proper initial comparison, however, again several data gaps had to be handled. Proper initial comparisons need especially long data collecting as they combine initial values of influence variables with final values of target variables of the reference projects.

Building this data collection, we introduced initial estimations of parameter values only after having had some experience and results from final comparisons, similar to the tentative collecting of goal weights. This is why the initial comparison shown consists of far less projects than the corresponding final comparison and could be executed only afterwards, because when starting the projects to be estimated – the last four projects of the collection – too few reference projects had already been finished. So it only serves as a study.

These, too, are reasons not to discard the improper initial comparison discussed in Sect. 6.4, in spite of its having a systematic error. Improper initial comparisons can be done with far shorter data collecting as they are restricted to final values of the reference projects.

The initial comparison table in Fig. 12.2 shows the characteristics evaluation of the initial data, i.e., the project objective when starting development. The empirical realization probability of each characteristic is given, too, hereby gaining useful additional information.

The initial comparison table requires the existence of quantified project subobjectives, even if they may be subject to changes later on. In Sect. 12.4, we want to discuss a different type of presentation of initial comparisons that does not need quantified subobjectives. Guide values or prognoses do not appear there, neither.

12.3 Star Charts

A different possibility of presenting individual project comparison results is by creating diagrams. Figure 12.3 shows an example where the final values of basic characteristics of project P177, already shown in Fig. 12.1, are presented in an octagonal form, a so-called star chart or polar chart. Therefore, this diagram is called a final star chart.

Numbers, goal weights, and higher-order characteristics have been left out to keep the chart easy to understand. The hatched area illustrates how strongly the project is oriented towards the respective goals.

The octagon shows the Difficulty of the subobjective in the top half, Keeping in the bottom one. On the left side, process characteristics and on the right side, performance characteristics are displayed.

Each corner of the exterior octagon corresponds to the scale value ten, the small circle – almost a single point – in the center of the octagon to the scale value zero.

Comparison Results for Project P177

Final Comparison (P001..P177) (Final Degree of Innovation,
Final Number of Items Planned,
Final Number of Different Parts)

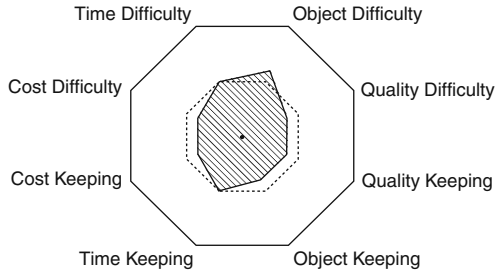


Fig. 12.3 Final star chart

The corners of the dashed octagon in the area between zero and ten correspond to the value five.

The hatched area deviating towards the center from the dashed octagon indicates characteristics values less than five – in our example, the value four. Where the hatched area deviates from the dashed octagon towards the outside, we have characteristics values larger than five – in the example, the value six.

In the same way, the results of an initial comparison can be presented. In Fig. 12.4, the initial star chart, the hatching has been modified to permit combining final and initial comparison results.

Comparison Results for Project P177

Proper Initial Comparison (P150..P173) P177 (Initial Degree of Innovation,
Initial Number of Items Planned,
Initial Number of Different Parts)

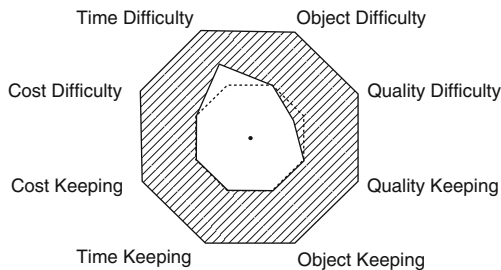


Fig. 12.4 Initial star chart

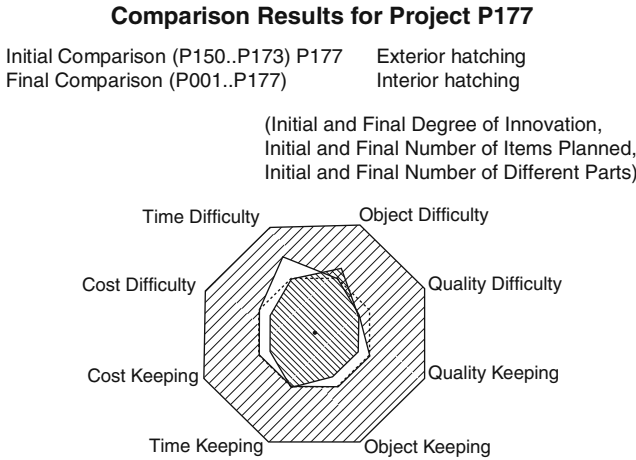


Fig. 12.5 Combined star chart

The scale is the same as in Fig. 12.3. Instead of the inner area, the area outside of the project line has been hatched. Without problems you can see where the project characteristics have passed above or stayed below the value five.

Figure 12.5 (combined star chart) shows the possible combination of the two presentations. The white areas in between the hatched areas represent final comparison results that fall below the initial comparison requirements. Overlapping hatched areas stand for final comparison results that exceed the corresponding initial comparison requirements.

12.4 Planning Charts

The planning chart, also an individual presentation mean, has been developed as a tool to support discussing and determining the planned finish date during early project stages. Figure 12.6 shows its most simple form, a line segment over a time axis. The same proper initial comparison of project P177 as in Sect. 12.2 and Figs. 12.2, 12.4, and 12.5, together with its predicted duration, is taken as an example.

Characteristically, the predicted project duration – or the corresponding project finish date, respectively – will not be given in the planning chart to avoid possible misunderstanding by outsiders as mentioned in Sect. 12.1. Instead of the predicted project finish date, only the line segment representing a certain range of this finish date is given.

Hereby we can show the considerable uncertainty inherent in the prognosis, prevent misinterpretation of the prognosis, and facilitate determination of a planned finish date that takes the prognosis as an orientation but not as a fixation. At the

Planning Chart for Project P177

Proper Initial Comparison (P150..P173) P177
 Index Corrected Project Duration (Initial Degree of Innovation,
 Initial Number of Items Planned,
 Initial Number of Different Parts)

Rough Connection between Planned Finish Date and Project Goodness

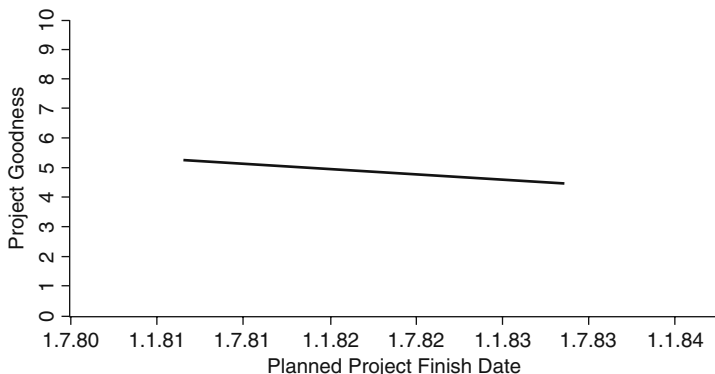


Fig. 12.6 Planning chart

same time, we can see how the date to be planned affects Project Goodness, for example.

Instead of one characteristic, the ordinate may show several. Thus the chart will contain several lines which may be based on different relationships [90]. Owing to the standardized scale for all comparison characteristics, no scaling problems will arise.

Projecting each of the lines onto the abscissa, we can mark a time interval, derived from the initial comparison, which with a certain probability will contain the actual finish date of the project to be planned. Projecting any one line onto the ordinate axis, we can mark the corresponding values of the initial characteristic concerned, which in Fig. 12.6 is only the initial Project Goodness, assuming otherwise unchanged requirements.

The probability of the actual project finish falling within the range indicated depends from the extension of the line segments, which can be chosen. In Fig. 12.6, the initial Time Difficulty values 4 and 6 have been selected as end points; based on the idealized normal distribution concept (cf. Fig. 8.5), the corresponding probability is about 68%. However, the interval may be stretched over the complete range of the initial comparison concerned.

As for calculation, the planning chart can be generated by re-transforming the model values chosen as end points of the line segment, here the project duration, into project values. As the initial comparison in Sect. 12.2 refers to index corrected,

not to nominal project duration, also the index correction of these two values has to be reversed to arrive at Fig. 12.6.

The method is the following: re-transformation and index correction reversal of the model values chosen result in two fictitious project values of initial project duration. These fictitious project values are added to the known project start date (= start of the conceptual phase), hereby yielding two fictitious finish dates. The corresponding values of the characteristic(s) chosen as ordinate axis are marked and simply connected by (a) straight line(s).

Because of the re- transformation, the project value of the guide value generally does not any more lie in the center between the fictitious finish dates. If any outsider erroneously assumed it to be in the center, this possible misunderstanding is insignificant compared to the considerable misunderstandings that presumably might result from indicating the planned finish date calculated from the predicted guide value.

Also because of re- transformation, the line segment shown stands for a line that actually is a slightly curved line. This inexactness can be neglected, considering the purpose of the chart.

The calendar date of presenting the planning chart to the persons concerned for scheduling purposes lies in the early stages of the project and before the initial finish date has been determined, i.e. far to the left outside the area of Fig. 12.6. I have tested this kind of chart based on improper initial comparisons and got satisfactory responses.

12.5 Time Series and Trend Charts

Now we return to multi-representation, namely to time dependent representation as a special kind. This kind of representation deserves intensified interest because it allows evaluation not only of project realization itself but also of its chronological development over a series of many projects. By this multi-representation, the inevitable inexactness in evaluating individual projects can be smoothed a bit.

Here, not only presentation of final comparison results, but also of initial comparison results or of any other project data can be of interest. We should be able to represent any aspect observed in an individual project also in a time series over many projects.

First, however, we have to solve a theoretical problem arising from the fact that a project is not a moment in time but in itself a process. The data and characteristic values we might want to illustrate are based on different collection dates, mainly start and finish of the project concerned.

At first, this does not seem to be a handicap. Knowing the start date and the finish date of each of the projects, we can mark selected initial and final values, e.g., initial Project Goodness and final Project Goodness, over a calendar axis, hereby getting one time series of initial Project Goodness and one of final Project Goodness.

Each one of these example time series is consistent and valuable in itself. But can we find time-dependent relationships between initial Project Goodness and final Project Goodness? Suddenly we come upon an evaluation problem.

Having marked the initial Project Goodness over the start date, the final Project Goodness over the finish date of the projects, we cannot immediately interpret the ups and downs of the two time series in relation to each other, because there may be years between the collection dates and thereby between the corresponding dates on the calendar axis. And having projects of long as well as of short duration, we cannot even numerically indicate the time shift between the two time series.

Combining the values of initial and final Project Goodness in one time series would not help. We would get a correct time series, but with a useless mixture of the two variables we want to represent separately to recognize relationships.

In the combined star chart (Fig. 12.5) we had combined initial and final comparison results of a project although their collection dates differed by years. This combination resulted in a meaningful contrast.

Such a contrasting would be desirable also for time series. So we have to find a reference date that all the data of one project – whether initial or final – can be assigned to. Then any one project will appear at the same calendar date in all of the time series to be considered. This is an arbitrary data manipulation, acceptable as long as we remember it in later evaluations.

Choosing start date or finish date of a project as its reference date, we would get enormous displacements of data for the respective other collection date, i.e. strong manipulation. The resulting time series distorts the proportions because with long projects the displacement is far greater than with short ones.

For this reasons, I would prefer to use the middle of the project – instead of its start or finish – as a fictitious reference date for contrasting time series, hereby smoothing the abovementioned distortions.

Figure 12.7 illustrates these considerations. The bold horizontal bars show different position and duration of five projects, the short vertical lines the respective central reference date. The time range of the representation thus will be shortened by half the duration of the oldest and the newest project, but the observation points corresponding to these reference dates are positioned more or less correctly with respect to the time axis.

The project data shown in the time dependent illustrations to follow always are assigned to this central date of the respective project, i.e. the arithmetic mean of start and finish date. Of course, also undistorted time series with the original reference dates of project start or finish may be useful for other purposes. The reference date should be indicated in the chart.

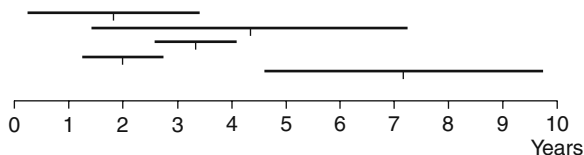


Fig. 12.7 Projects as bars and points on a time scale

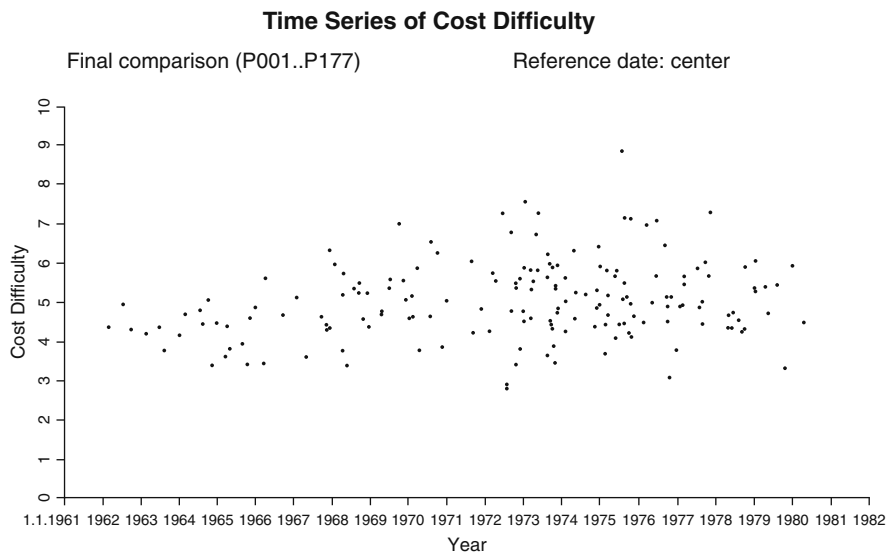


Fig. 12.8 Time series of Cost Difficulty of the 177 projects

Figures 12.8 and 12.9, using this reference date, show the time series of Cost Difficulty and Time Keeping of the Total Comparison discussed in Chap. 11. In Figs. 12.8 and 12.9 again appear the outliers from Figs. 11.1 and 11.6, as the values represented only have been sorted differently; instead of the guide value, the abscissa now is time.

Indistinctly, in Figs. 12.8 and 12.9 we can observe a certain time dependency of the average vertical position of the values, i.e., a trend. This trend can be highlighted by again fitting a balance line to the set of points.

The analytical considerations from Sect. 8.1 are still valid without much alteration. Being interested here only in the time dependency, we can replace the various influence variables by different powers of time. Hereby, we get balance functions that may be curved, thus representing the trend more exactly than a straight line.

The trend charts to follow are based on balance functions containing first, second, and third powers of time. As an observed time variable, we take the working-day number (date) from the working-day calendar explained in Sect. 10.2.1. The definition for this balance function is

$$\hat{y} = a + b_1x + b_2x^2 + b_3x^3$$

where

x = reference date

\hat{y} = trend of any project property y

The symbols x , y , and \hat{y} are used here somewhat differently. We will talk about details in Sect. 13.6.

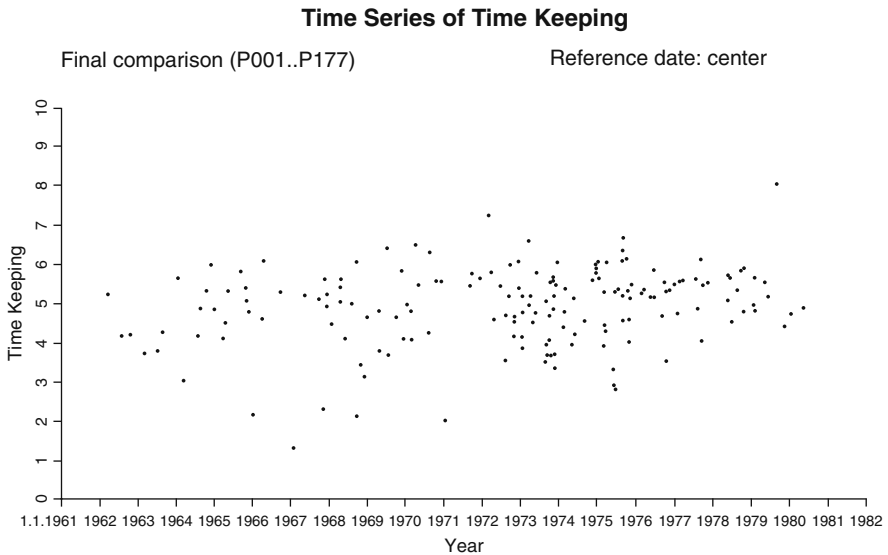


Fig. 12.9 Time series of Time Keeping of the 177 projects

Figures 12.10 and 12.11 illustrate the two trends of Cost Difficulty and Time Keeping. The calculation may be executed by means of the same DP programs as in Chap. 8; as it only is a tool to arrive at the chart and basically does not give any new insight, the balance functions, which are structurally the same, are not listed here.

Neither are significance or degree of determination of any importance, as we only want to consolidate scattering values and not to draw any inferences. The balance functions of Figs. 12.10 and 12.11 had a significance level of 5% and a degree of determination of about 0.1.

Now we can give details concerning the supplementing of the defect rate FIQ (FIQ = final/initial value ratio, cf. Sect. 11.2) mentioned already in Sect. 11.2. Figure 12.12 shows the supplemented time series, Fig. 12.13 the supplemented trend chart.

For the first 112 of the 177 projects, the final values of defect rate FIQ were missing. For this reason, the Partial Comparison of Quality Keeping had to be restricted to the existing 65 values. The right hand part of Fig. 12.12 shows the result.

The Quality Keeping of the other 112 projects as a whole was assumed to be 5, as the left hand part of Fig. 12.12 shows. The overlap of the two parts is due to partially retrospective estimations of the initial defect rate.

The defect rate FIQ only has a goal weight of 3 out of the overall goal weight of 72, to be seen from Sect. 11.2. Therefore, supplementing missing values appeared to be acceptable, hereby allowing presentation of higher order characteristics based on Quality Keeping and particularly their long-term development, in spite of partially lacking data.

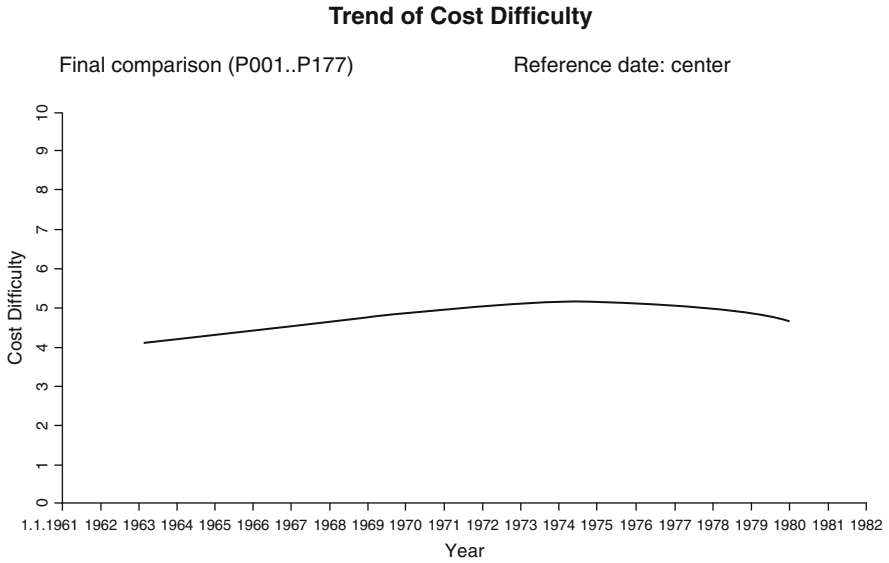


Fig. 12.10 Trend chart of Cost Difficulty of the 177 projects

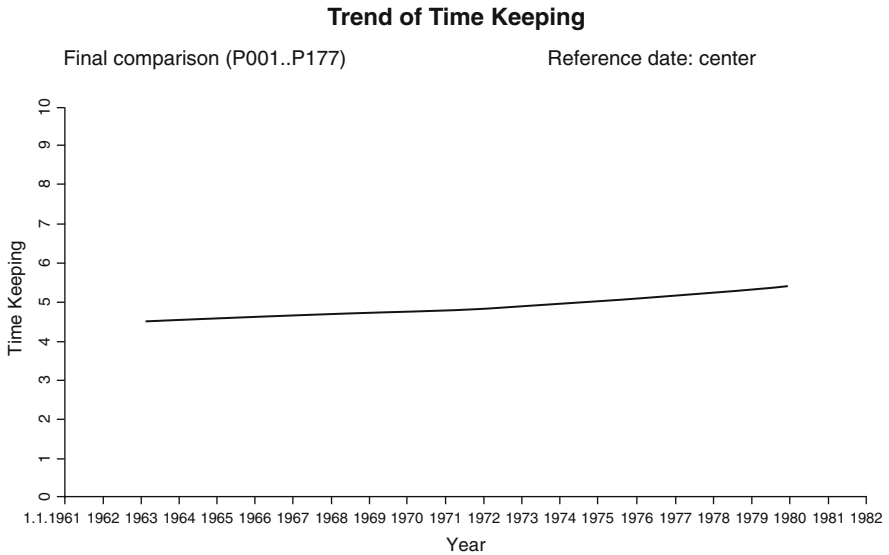


Fig. 12.11 Trend chart of Time Keeping of the 177 projects

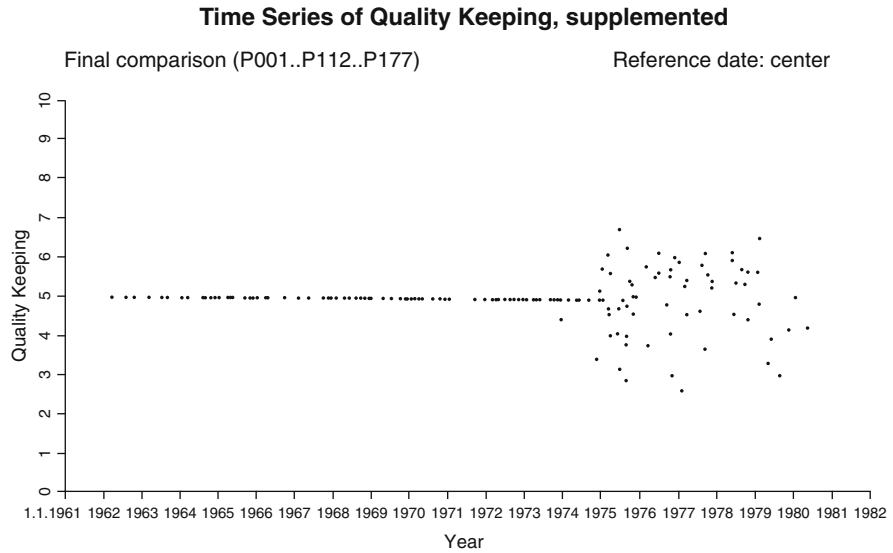


Fig. 12.12 Time series of supplemented Quality Keeping

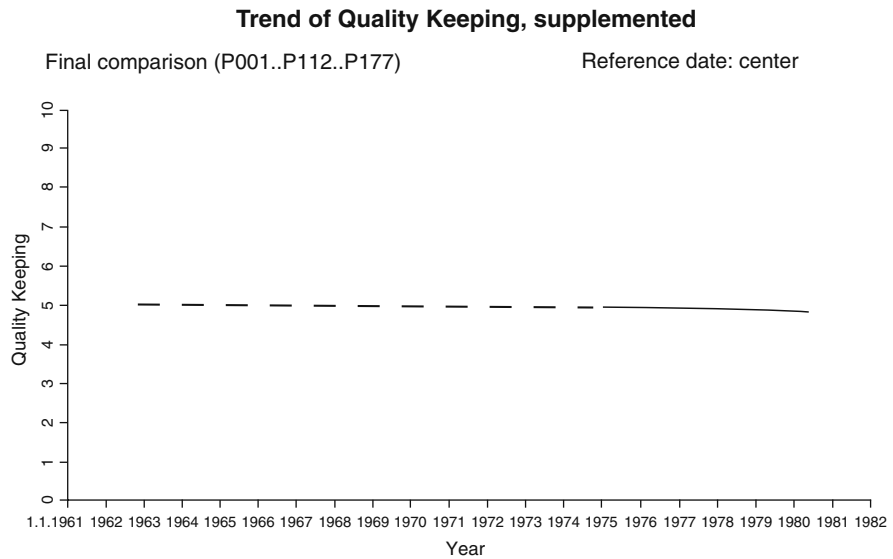


Fig. 12.13 Trend chart of supplemented Quality Keeping

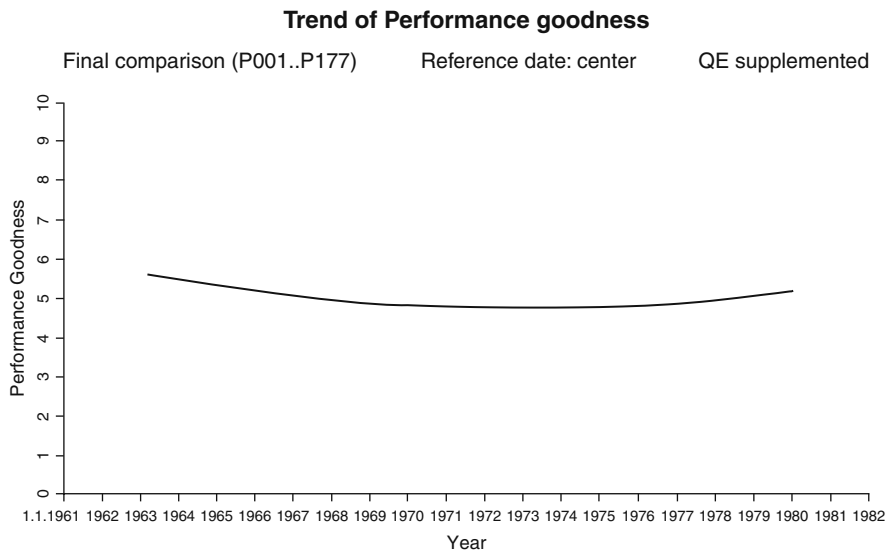


Fig. 12.14 Trend chart of Performance Goodness of the 177 projects

A completely different situation from the trend charts considered so far can be seen in Fig. 12.14, the Performance Goodness trend chart, sagging perceptibly in the middle of the observation period. As we have just explained that the defect rate FIQ, contributing to Performance Goodness as a goal, was assumed to be more or less constant, the sagging has to be caused by the goals production costs and defect rate itself.

For an explanation, I would think this sagging might be caused by the technical and organizational changes during the observation period, mentioned already in Sect. 9.3.3. At that time, the chart could not be presented and promptly discussed; but new material, production methods, and processes presumably had unfavorable effects upon production costs and defect rate, until experience had been gained.

Nevertheless, Time Keeping was improved during this period, as shown in Fig. 12.11, in fact not only when in 1972 central scheduling and controlling was introduced but before. The various trends highlight how little uniformity there can be between goals of projects.

All the more interest then lies on the issue of how the projects developed combining all goals and goal weights. Also when considering trends, the project as a whole is the viewpoint which is the most decisive.

Figure 12.15 illustrates the changes of Project Goodness over time. In a softened way, the sagging of the Performance Goodness can again be detected, but towards the end of the observation period, the Project Goodness of the beginning had been restored.

Figures 12.16 and 12.17 show the contributions of Project Difficulty and Project Keeping to the Project Goodness in Fig. 12.15. With Project Difficulty, the sagging

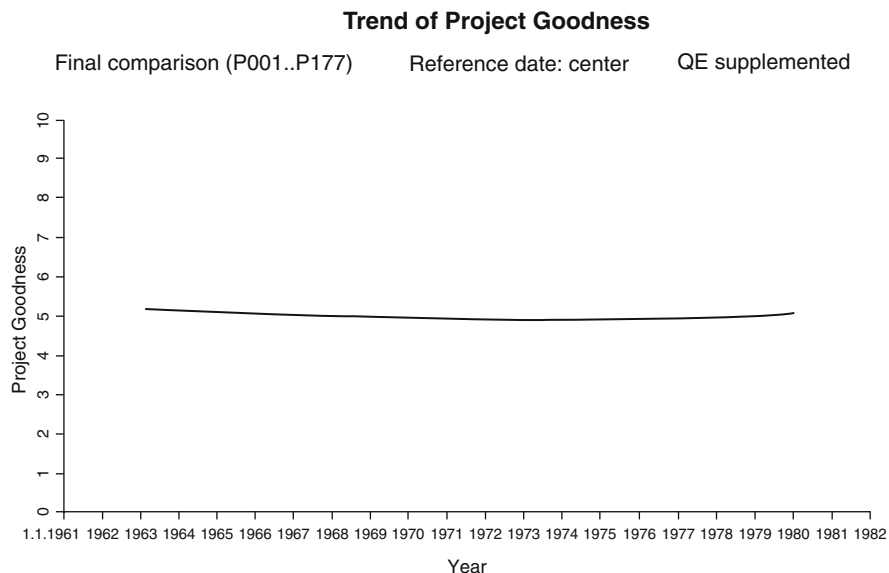


Fig. 12.15 Trend chart of Project Goodness of the 177 projects

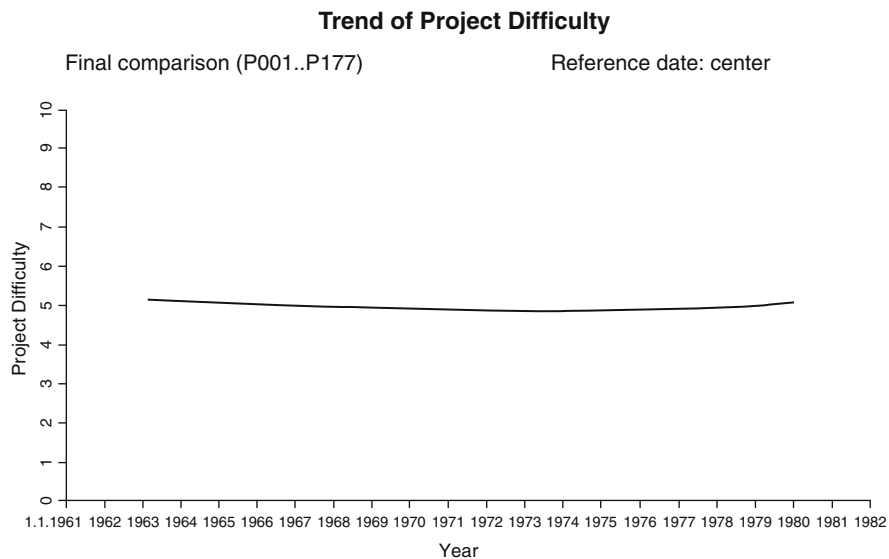


Fig. 12.16 Trend chart of Project Difficulty of the 177 projects

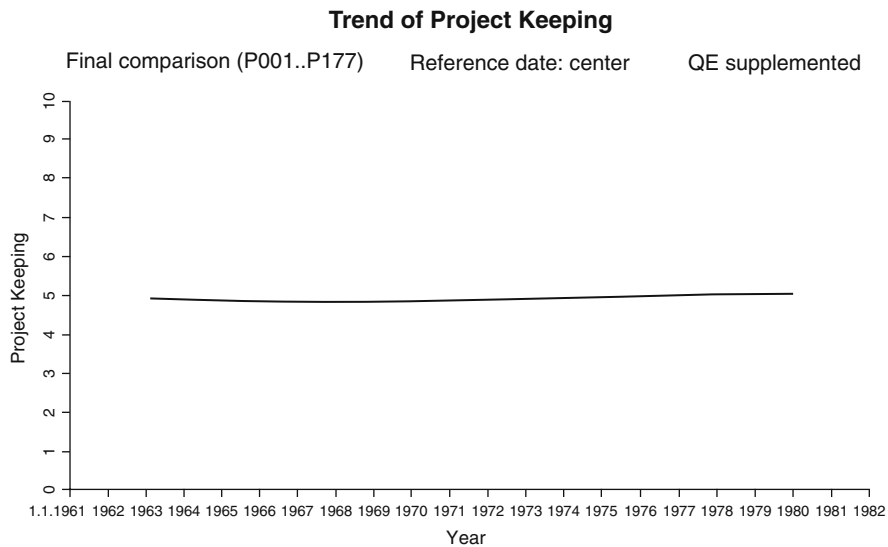


Fig. 12.17 Trend chart of Project Keeping of the 177 projects

can again be observed, whereas Project Keeping shows a continuous rise after an initial small decrease.

Of course, the trends of these highest-order characteristics of our evaluation system deviate from the value 5 only by a small amount, because averaging several times will soften any differences either between the base characteristics or between the projects concerned. Because of this smoothing effect, however, trend charts of Project Goodness as a top level characteristic offer a high degree of credibility, which goes well with the special implications of the term Project Goodness.

Chapter 13

Application Issues

13.1 Getting the Parameters

13.1.1 How to Search for Parameters

Every type of projects and every branch has its own project parameters. Search for and selection of parameters require expertise and experience from corresponding projects, the more so as some parameters need their own special scale or can be estimated only subjectively.

In contrast to goals and goal weights, parameters expand our usual understanding of projects. We may handle project parameters daily; we even take into account their relation to goals. But the term parameter is new in connection with projects, and deliberate experience with parameters and parametric analysis is scarce. How do we determine parameters for project comparisons?

We are used to recognizing volume and difficulty of projects by looking at the object and maybe at costs and duration of the project: we know that building an ocean liner is more complicated than building a sailing boat, that building a metropolitan subway network is more difficult than building a bicycle lane, etc. We need not know about parameters to recognize this.

Just because of this, we might get new ideas concerning parameters asking ourselves how we would distinguish between “big” and “small” projects in our branch if we knew nothing about object, costs, and duration of the projects. Maybe by means of the number of participants? The number of necessary authorizations? The number of detailed plans to be prepared? Material consumption? Risks?

Thus, temporarily neglecting the former main variables we can get a better view of possible parameters. In this way, I found the following parameters for the projects described in the present work: degree of innovation, number of items planned, number of different parts, and retail price of the product.

Another useful question is the following: apart from distinguishing “big” and “small” projects, what process or performance properties of our projects might have a considerable or noticeable effect on goals?

By asking myself this question, I found some more parameters: external contribution to the product, relative degree of scheduling (cf. Sect. 10.1 and [87]), relative

duration of central scheduling, urgency of the project, and finally, temporary accumulation of projects in a department or at the site.

Of course, this selection mirrors the circumstances present in the scheduling department during my first project comparisons, stressing the data that could be collected with little additional effort. Everybody will start by choosing parameters that come up anyway in the course of the project or can easily be provided for.

Some help in looking for parameters can be found by searching separately for natural and for modal parameters, because concentrating on one of these areas will force us to think more clearly. Further ideas on parameter determination can be found in the examples of Sect. 3.2 and in the books on parametric cost, time, and effort estimation cited in Chap. 14.

13.1.2 How to Select Parameters

We may safely assume that even with careful preparation not all of the parameters found but perhaps only half of them will actually prove themselves useful unless we have copied a well-trying set. Usually, a certain risk in collecting parameters will be inevitable.

For example, with the projects detailed here, the following parameters were used only temporarily: urgency, because of its overlapping goal weight and Difficulty of project duration; retail price of the product, because of its being dependent from production costs and number of different parts.

All the same, there will probably be always enough parameters to do comparisons. With some projects, we may even have so many parameters that we find the choice difficult. A fictitious technical example:

Developing a new car model, we might propose maximum velocity as an object goal. As a parameter for the corresponding balance function, we might choose the size of the wing mirrors.

Certainly, there is a causal relationship in the aerodynamic resistance of the wing mirrors; but is it strong enough to contribute noticeably to the maximum velocity, considering usual mirror sizes? Perhaps horsepower, weight of the vehicle, rear form, windshield inclination, and several more possible parameters are more effective? So maybe we would strike off some of the parameters found.

Because of the necessity to present and discuss comparison results parameters should be easy to be understood and preferably already known throughout the company. Ratios or mathematical products of different quantities are intransparent; furthermore, they brought dissatisfying results in my experiments, in spite of showing apparent logic.

Transparent and meaningful interpretation is most important with comparisons designed to result in binding evaluations and to stand up to critical discussion. In the projects I have evaluated so far, results had been satisfactorily interpretable when I was using two to four influence variables; therefore I would recommend staying near these values, at least initially.

Aside from this, using influence variables derived from quasi-parameters as considered in Sects. 6.2 and 8.7 might give interpretation problems to outsiders. Partially, at least, these are more sophisticated approaches, in spite of being justified by their practical importance.

Sometimes we come upon the statement that only parameters leading to a positive block value in the balance function are appropriate influence values. Negative block values, e.g., negative project duration – i.e. time gain in the case of an extrapolated influence value of zero – are declared unrealistic and wrong.

This statement is erroneous and is caused by mistaking the balance function for the true causal relationship whose mathematical function we do not know. Extrapolating the balance function outside the collection range always is dangerous and may lead to absurd results. This is not a sign of balance function or parameters being useless.

The most robust parameters will be found with natural parameters, not with modal parameters. Any project comparison completely lacking natural parameters appears somewhat meaningless. But joining modal parameters to natural parameters can be interesting because of their allowing conclusions concerning the effects of management tools and measures. This will be the topic of the next section.

13.2 Effects of Individual Parameters

In favorable cases, we can analyze the effects of individual parameters by means of project comparisons. We want to demonstrate an example using project costs as a goal.

In the course of our Total Comparison, we have looked at project costs in dependence of degree of innovation, number of items planned, and number of different parts. Now we want to integrate a fourth parameter: relative degree of scheduling, using the variable X_{100} , i.e. final relative degree of scheduling.

For the projects considered, the relative degree of scheduling was defined as the ratio of the actual number of network plan activities and a fictitious economical number that had been calculated from an industry-wide study in 1974/1975 [87]. The initial and the final relative degree of scheduling had been collected for every one of the 177 projects; in cases where no network plans existed, this has been substituted by means of other scheduling specifications, e.g., conference protocols.

In contrast to the natural parameters used so far, the relative degree of scheduling or number of scheduling levels is a typical modal parameter, which can be handled to the discretion of the project manager. The definition used in this case has a weakness, however: the economical number of network plan activities mentioned above is related to project costs, i.e., to a goal.

A similar case is the relative duration of central scheduling mentioned in Sect. 13.1.1 as a parameter; its definition is related to the goal project duration. The indirect relationship to goals links both parameters to quasi-parameters. We will soon get back to this issue as far as the degree of scheduling is concerned.

Including an appropriate influence variable X_{100}' , e.g., $\sqrt{X_{100}}$, in a Partial Comparison, of course we will get a somewhat different balance function than that of Fig. 11.1 in Sect. 11.4, irrespective of the relationship issue mentioned above. Have a look at the balance functions side by side:

Old balance function:	New balance function:
$\ln Y_{026}^{\wedge} = 3.67275$	$\ln Y_{026}^{\wedge} = 4.44223$
$+ 1.15779 * \ln X_{033}$	$+ 1.07276 * \ln X_{033}$
$+ 0.31431 * \sqrt{X_{035}}$	$+ 0.29134 * \sqrt{X_{035}}$
$+ 0.69166 * \ln X_{036}$	$+ 0.60158 * \ln X_{036}$
	$- 1.00950 * \sqrt{X_{100}}$

The minus sign with $\sqrt{X_{100}}$ indicates that the new influence, contrary to the others, worked to lower the guide value, i.e., to save project costs. This is not surprising as scheduling is a tool to organize project realization in an economical way, e.g., avoiding idle times and capacity overload. For many of the projects, the relative degree of scheduling was rather low, i.e., few dates had been fixed.

Increasing the degree of scheduling meant more details scheduled and thus better organization. With project P177, for example, according to the new balance function, increasing the degree of scheduling by, e.g., 10% would have corresponded to decreasing the project costs by 1%. Of course, the result must not be extrapolated outside the collection range in order to avoid possibly absurd conclusions.

As the relative degree of scheduling had been defined in relation to project costs, in consequence the degree of scheduling actually would exceed 10%. Decreasing the project costs by 1% would increase the actual raise in the degree of scheduling by that percentage, i.e., from 10 to 10.1%. Considering the inexactness of the method as a whole, however, we may neglect this error.

Apparently, visible effects of the parameter being related to the goal are small. All the same, we should try to avoid such relations.

Figure 13.1 shows the trend chart of the new balance function. We can see that the trend here is considerably flatter than that of Fig. 12.10. How can this flattening be explained?

According to Sect. 8.1, block value and scatter value together constitute the influences that can not be identified individually. In result plots, in time series, and – in a condensed form – in trend charts, only the scatter value will be seen; the block value and the influences identified individually do not show.

In Fig. 12.10, the influence variable X_{100}' is contained in the scatter value shown, but not in Fig. 13.1, because here it is one of the influences identified individually and so taken out of the scatter value. So, the difference between the lines of Fig. 12.10 and Fig. 13.1 corresponds to the scattering contribution of influence variable X_{100}' .

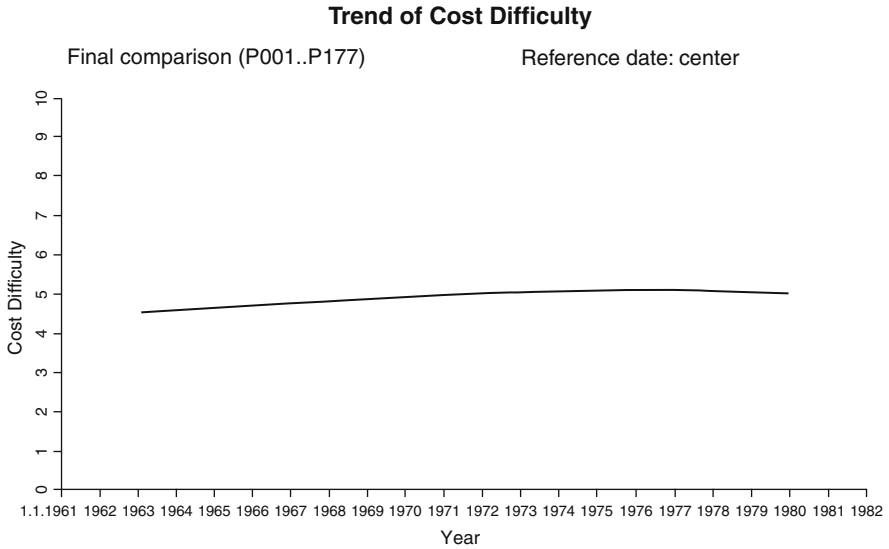


Fig. 13.1 Trend chart of Cost Difficulty with new balance function

We can use a little trick to verify this point: In Fig. 13.2, the trend chart of Fig. 13.1 is shown once more (thick lower line), but additionally (thin upper line) without the component $1.00950 \cdot \sqrt{x-100}$.

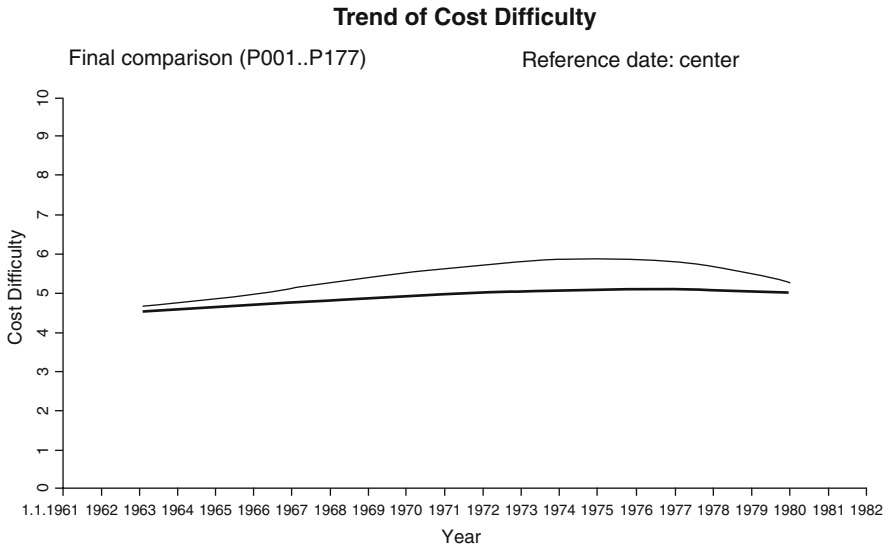


Fig. 13.2 Trend chart of Fig. 13.1 with a part of the new balance function (thin upper line)

Thus, the upper line shows a partial function we can indicate by '' :

$$\ln Y026'' = 4.44223 + 1.07276 * \ln X033 + 0.29134 * \sqrt{X035} + 0.60158 * \ln X036$$

Of course, the upper line is not any more a balance function, but we can see that the curvature of the line is similar to Fig. 12.10. So we can deduce that the marked maximum of Cost Difficulty in 1974–1976 is not based on the little differences of the influence weights of old and new balance function but actually on the influence variable X100'.

Not only analytically, but also graphically in the trend chart we have thus convincingly shown that degree of scheduling and project cost saving had run parallel during that time. In this way, by means of project comparisons, relationships can be recognized relevantly and quantitatively and so can be used to improve projects. This is a real and detailed example of how to meet the desire to have methods for measuring management tools, management actions, and management performance.

Note: This does not imply that degree of scheduling and project costs really had a causal relationship, which would mean that degree of scheduling might have been used to control project costs; nevertheless, the analytical relationship would motivate corresponding tests. Had I known the trends at the time, I would have proposed to run maybe 5–10 projects with the higher degree of scheduling of 1974–1976 and to observe whether the cost trend improved in consequence.

13.3 Stability of Project Goodness

All project comparison characteristics are relative; they are valid only for a specific comparison constellation. For application of project evaluation, however, we would like to have stable results that are independent from how they have been reached.

In the comparison tables, Sect. 12.2, all characteristics have been given in whole numbers because of their low exactness and the stability mentioned. The star charts, Sect. 12.3, are based on the same whole number values.

Project Goodness has a special importance, being the one characteristic comprising all goals and being the most condensed mean, i.e. the most significant of all characteristics. With the other characteristics, possible instability is less awkward.

For this reason, I counted how often the same project got distinctly different Project Goodness values in different Total Comparisons, including the smallest possible number of projects (p+2) up to the highest possible number (177). In these comparisons, the Quality Keeping characteristic had been supplemented, where necessary, in the way shown in Sects. 11.2 and 12.5.

Naturally, comparisons of large numbers of projects performed better than those of small numbers of projects. Total Comparisons with different parameter structure, but always 177 projects, showed significant differences in Project Goodness for about 5% of the projects. For smaller numbers of projects, but more than 25,

such a difference arose with 10%, for still smaller numbers with about 30% of the projects.

However, the Project Goodness observed never varied for more than one unit. Example: any project with Project Goodness 5 in any one comparison might have a Project Goodness value of 4 or 6 in any other comparison, but it never happened to have the value 4 in one and the value 6 in another comparison.

I think that this stability of Project Goodness is sufficient. The fact that basically Project Goodness is a relative quantity is communicable also to outsiders, and borderline cases that lead to shifting evaluations to an adjoining category are known from many other areas and so can be tolerated.

13.4 Organizing and Communicating Your Work

Handling balance functions usually is the work of few persons; they could be called analysts [48]. Unnecessarily passing on balance functions may affect impartial estimation of parameter values that often is necessary, and cause misunderstandings with inexperienced persons. The same holds for prognosis values that have not yet been edited.

With presentations of results, the situation is different, as they are meant to be passed on. For the benefit of stability, as mentioned in Sects. 11.5 and 13.3, these presentations will be based on as large numbers of projects as possible, and the balance functions involved should not be changed overly often. Maybe a fresh version of a balance function every year could be appropriate, even if that need not limit the analysts' work.

We should also be aware of the risks, mentioned in Sects. 5.3 and 12.1, of hastily interpreting comparison results as related to persons and of evaluating these results erroneously according to planning standards. This risk is increased by the fact that regression analysis is known to be an exact and strong tool.

Both of these risks have to be counteracted, for example, by stressing the inexactness of the comparisons and their dependence from suppositions and selections. In his article, Schwald [66] quotes several tips about how to handle characteristics generally.

Furthermore, outsiders sometimes do not differentiate between descriptive and inferential comparisons, asking for significance and high degree of determination of balance functions also with descriptive comparisons. This is not a really far-off idea, as regression analysis often is used for inferential purposes in statistics, and parametric estimation of cost, time, and effort, as well as initial comparisons actually are used for prognosis.

In this context, I have learnt to avoid statistical terms such as regression analysis when communicating with outsiders, and to state clearly that exclusively calculating a balance function and descriptive comparisons does not involve any prognostic elements and so is free from the requirements mentioned.

13.5 Exogenous Planning and Controlling of Project Progress

13.5.1 Purpose

Initial Partial Comparisons of Base-Goals can be supported by means of simple non-parametric comparison tools to yield exogenous process planning. Doing this, we build prognoses for details of the project realization, e.g., for phases or milestones, i.e., for the project progress planned.

This makes exogenous progress control for a project possible. It can be used along with the endogenous progress control for a project used in project controlling [29], adding comparative evaluation of time risks or cost risks, for example. So, the degree of difficulty of the measures to be taken will become visible and can be taken into account in project controlling.

Because of the special data base and method of this kind of prognosis, so far we have mentioned it only in passing. Now we will demonstrate an example for time planning and controlling. This example can be extended to costs and other project variables that may be suitable [15].

13.5.2 Data Base

Starting in 1971, the schedules for the projects considered in this work were based on standardized network plans, which could be reduced or extended according to need, but which had a core of standard activities with fixed activity numbers. Figure 10.3 in Sect. 10.2.2 contains two of those activities.

To be able to compare the experience values out of these standard activities, apart from calendar dates, also relative start and finish dates of these activities were established, given in per mill of project duration and using the project start as origin. In Fig. 10.3, the variables YE2862 and YF2862 are of this kind.

The relative quantities were tabulated, grouped by product type, and sorted by frequency. Figure 13.3, as an example, shows part of camera pilot production dates. These tables containing per mill distributions, in German “Promilleverteilungs-Tabelle”, were being called “Provelle” for short.

Activity	Activity Number	YE2862	YF2862	Frequency
Pilot Series	2862	721	820	Minimum
		915	924	25%
		944	953	50%
		959	965	75%
		970	989	Maximum

Fig. 13.3 Part of the “Provelle” for cameras, status date 1981-3-10

Figure 13.3 can be read in the following way: for this kind of projects finished by 1981-3-10, pilot production was started (YE2862) after 72.1%(=721 per mill) of the project duration at the earliest, after 97.0% of the project duration at the latest. With 25% of the projects, this start date was at up to 91.5%, with 50% at up to 94.4%, and with 75% at up to 95.9% of the project duration.

The pilot series finish dates (=YF2862) are to be read in the same way. By way of precaution, I would like to point out that in Fig. 13.3, the numbers referring to start and finish dates generally do not correspond to one and the same project, so we cannot derive the pilot series duration out of their difference; pilot series duration was being recorded separately in a variable of its own. For initial planned values, some further variables were in use.

In order to calculate the values of relative start and finish dates corresponding to the quantiles 25%, 50%, and 75%, the values concerned first were sorted numerically. Then we simply counted up to the percentage concerned. Together with the same information gathered for about ten other key activities of project realization, the per mill distribution tables contained a rough rule of thumb schedule of similar projects.

13.5.3 Application

Of course, we might now parametrically estimate start and finish dates of the standard activities, the data of which were contained in the per mill distribution tables, like we did with other goals of new projects. This would be rather cumbersome and flawed by the inexactness of the parametric method and by the constraint to adjust intermediate dates to each other and to a prospective finish date.

I thought it simpler and more exact to wait for a finish date being known or proposed and then inserting the exogenous relative schedule in between the project start already passed and the planned finish date. Having the values in per mill of project duration, we could easily adapt them to different project durations of new projects and convert them to calendar dates, using the project start already passed (= start of conceptual phase) as a reference.

In a first step to establish possible planned finish dates, we used the planning chart discussed in Sect. 12.4. As soon as detailed ideas or alternatives of the planned finish date emerged from the discussion, the exogenous schedule of the corresponding per mill table was adapted to the range between the planned finish date being discussed and the project start already passed and spread over this range – similar to a hammock between two trees.

The 50% values quickly served as a rough schedule draft for discussion with the departments. The 25%, 75%, and extreme values served as an orientation when changes or delays occurred during project realization.

Naturally, using these per mill distribution tables, we were counting on the assumption that similar projects are similar or approximately proportional also in the details of activities. I have never checked this assumption and never had compelling

reasons to check it. The departments concerned welcomed these schedule drafts as simplifying planning and discussion.

13.6 Objective-Independent Terminology

At the end of this chapter, I want to present a necessary addendum to the basic principles of Project Comparison Technique:

All our considerations so far were based on the objective structure of our projects (Chap. 2). The objective structure shapes the system of characteristics, the goal prognoses to support planning, as well as the terms of the Parametric Project Model which we used for our calculations. The target variable so far always was a goal form, the influence variable always a parameter or quasi-parameter form.

Project Comparison Technique, however, goes beyond these considerations. Goals are not the only values to be evaluated and forecast.

In the course of a project, questions may arise about relationships between one parameter and another. For example, in a track building project, the relationship between track length and amount of land to be bought may be of interest. Both of these quantities are parameters.

This question can be answered by doing a project comparison. If project evaluations or prognoses are executed routinely, finding the answer is especially easy because several data, corresponding calculation methods, and expert staff (analysts) already are available.

Handling this new question, we also can keep our decomposition equation

$$y = a + bx + h$$

without change. In this case, y is not a goal form, but some form of a parameter, e.g., amount of land to be bought, and x is some form of another parameter, e.g., track length, where both parameters, transformed if necessary, have to show an approximately linear relationship to each other.

Already when we were talking about the trend formula in Sect. 12.5 we began to use x , y , and \hat{y} in a slightly different way than with the Parametric Project Model. Implicitly, we also have drawn back on the requirement that y had to be causally dependent from x : similar to Sect. 13.2, also relationships with uncertain causality can be of interest, even though with the risk of being deceived by pseudo-causalities and knowing that they are not suitable for evaluating projects.

Relaxing our requirements in this way, especially without y being a goal form, corresponds to passing from the Parametric Project Model to another one, freely chosen, that is not supposed to be linear or to require major similarity between projects. y need not be subject to a requirement in the sense of a project objective, there even need not be any project at all. Maybe we only want to find out about a technical relationship without thinking of any predetermined evaluation purpose.

Letting go of the requirement of Sect. 2.3.1 of maximizing or minimizing some value, respectively, we also can omit the double requirement treated in Sect. 2.3.2 and the differentiation between Difficulty and Keeping. In the preceding example about track building, choosing any one of the terms – Difficulty and Keeping – would be difficult and would give a certain unintended interpretation to the results.

The term Goodness is even less appropriate in this case. Neither is there a Total Comparison.

For this reason, I would suggest to use a “neutral” term for the quantity so far called Difficulty or Keeping, to avoid distortions of interpretation in cases such as this track building example.

In these cases, I like to use the term “declination” instead of Difficulty and Keeping.

$$\frac{\pm h}{s} + 5 = \text{declination,} \quad \text{avoiding the terms Difficulty or Keeping.}$$

The sign with h can be chosen according to the application. In some cases, the scatter value h is sufficient for the evaluation intended, so we may not even need the term declination. If necessary, declination can be abbreviated by D.

Similar to the terms Difficulty and Keeping, the terms target variable and influence variable rely on the objective structure considered so far. Here, too, a different task might present difficulties in understanding, e.g., if y is not a goal form.

Here a suitable alternative consists in using the neutral terms “dependent variable” and “independent variable” already mentioned in Sect. 8.1.

To summarize: If need be, we can substitute the following terms

target variable	→	dependent variable
influence variable	→	independent variable
Difficulty S or Keeping E, resp.	→	declination (D).

Chapter 14

Specialized Prognosis Methods for some Base-Goals

14.1 Notions

In the USA, already for several years project data have been collected and prognosis methods of some Base-Goals have been developed, usually called estimation methods. Examples are the parametric methods PRICE, COCOMO, and function point for estimating project costs, duration, and effort.

In the present work, which has been developed without reference to these specialized methods, prognoses have been treated in connection with initial comparisons (Sects. 6.3 and 6.4) in a general and basic way. But beyond that, the special importance of project costs, duration, and effort has induced not only the examples mentioned in the preceding chapter, but also many more studies and publications, some rather substantial and sophisticated, on different prognosis methods of these Base-Goals [cf. 1, 6, 11, 13, 14, 24, 28, 48, 53, 60, 61, 64, 65, 67].

To my knowledge, these studies are restricted to isolated Partial Comparisons, apparently improper initial comparisons. So far, I never encountered an approach to proper initial comparisons or Total Comparisons.

Often parametric and non-parametric methods have been combined or non-parametric methods alone have been used. Schelle [63] calls the field of metrics in IT projects a subsection of computer science. Two of our three examples are taken from this field.

Because of some general points, we want to have a look at the three examples. For more information, you might want to read some of the specialized books.

14.2 Price

According to their own information, the RCA Company developed PRICE in the early sixties. Apparently, preliminary work had been done in 1957 by Franc R. Freimann [54].

Since 1975, PRICE has been offered commercially to customers outside the company, who do not get to know the data base and the balance functions. Calculations are done by remote computing in the USA, nowadays by PRICE Systems, L.L.C., receiving the customer's project data and returning the prognosis.

The company offers four different estimation possibilities: PRICE H (hardware costs of electronic, electromechanical, and mixed products), PRICE HL (life cycle costs of hardware systems), PRICE M (micro-electronics elements costs), and PRICE S (software development costs).

The main worth of this offer for outside customers is the comfort of having ready-made instructions and the considerable and still growing size of the system owner's data base, presumably resulting in stable calculations from the beginning, even though arrived at in an intransparent way and therefore not available for retracing [28]. In 1999, thousands of handled projects and thousands of mathematical equations were reported.

Madauss [53], knowing the application by own experience, describes PRICE H (hardware) in detail. Summing up several calculations on an assembly level reduces the inexactness of the method. The following seem to be used as main parameters for hardware costs [55]: batch size, number of prototypes, weight, volume, platform (operating system requirements), complexity of production, complexity of development, and some kind of accounting for start and finish dates of development and production.

To enable the customer to estimate the different types of complexity with his own projects, during several months of preparation and calibration, examples of his own past projects were taken and calculated backwards using PRICE, resulting in complexity values to be used as hints for estimating new projects [55]. This is the course of action recommended by PRICE Systems, revealing some uncertainty and difficulty in handling external project data.

As calibration requires data from own past projects, these have to be defined and collected sufficiently; being probably the weakest link in the data chain, they will decide about the validity of the prognoses. In this case, it seems self-evident to execute one's own initial comparisons using the goals and parameters needed for calibration anyway. The prognoses resulting from these comparisons will correspond better to the special circumstances of one's projects.

This will avoid the risk of interpreting, second-guessing, and maybe even misinterpreting external goals and parameters, and assuming certain external circumstances; all this being a source of additional inexactness. Furthermore, doing one's own initial comparisons offers the opportunity of getting statistically based error estimates, of comparing the results with PRICE results, and of extending the comparisons beyond the prognosis itself, as treated here.

14.3 COCOMO

COCOMO (= Constructive Cost Model), which is a method for prognosis of effort and duration of software projects, is a lot more transparent than PRICE. It has been developed by Barry W. Boehm and is described in his book "Software Engineering Economics" [1, 6], which has been published in 1981.

Boehm's studies were based on 63 projects of different kind from the years 1964–1979, realized and documented by the TRW Company. Data, variable

definitions [4, 9], and study results used by Boehm are published in the same work; this amounts to good, although not perfect, transparency, and an instructive example.

Boehm intended [5, 10] to create a system of fixed equations and multipliers (or a recipe) for estimating effort and time, which was supposed to be concise and valid for all kinds of software projects. COCOMO – similar to PRICE – was intended to spare the user the trouble of doing his own regression analysis, but, in contrast to PRICE, it is an expert method in the sense of Sect. 1.5.

COCOMO goals are development effort in man-months (MM) and the duration of development (TDEV) in months. The development effort parameter is the number of thousands of program instructions to be executed (KDSI, kilos of delivered source instructions). Development effort is being used as a quasi-parameter of development duration [2, 7].

Boehm defined six basic equations, all of the type

$$MM = 2.4 (KDSI)^{1.05} ,$$

with factors varying between 2.4 and 3.6 and the exponents between 1.05 and 1.2, in order to correspond to well-defined differences between projects and applications. For effort estimation, he created 15 multipliers (values between 0.7 and 1.66) and some fine-tuning possibilities.

Three of the effort estimation equations are designed for moderate demands, without multipliers or further adaptation, the other three for the use of multipliers and other fine-tuning tools. For the latter, he combined parametric and non-parametric methods [64, 65].

For time estimation, Boehm defined three equations of the type

$$TDEV = 2.5 (MM)^{0.32} .$$

Between these three time equations, only the exponent varies (from 0.32 to 0.38).

Boehm admits [3, 8] that for the benefit of being easier to understand and better fitting to each other, his nine equations are not balance functions (best fit functions) corresponding to the least squares method. So far, I have not found an indication of how Boehm arrived at his equations, and so, an evaluation is difficult.

I would think that there is a certain risk to stability in the fact that Boehm apparently defined rather a large number of variables using a relatively small number of projects, i.e. his project file or its subgroups. For the creator's project file, relatively good adaptations are possible in this way, but transfer to outside projects may prove to be unsatisfactory.

Boehm offers calibration of his equations and variation of his multipliers [5, 10]. Calibration, however, is not sufficient to counteract obsolescence of underlying data and quantitative relationships, and it involves additional inexactness.

In this context, Boehm indicates the possibility of the user re-calculating his equations and multipliers, using suitable substitutions. This seems to me more appropriate than calibration. The user gets deeper insight and adaptability of his

prognosis and can contrast it with the COCOMO results, kind of a comparison across companies.

In this case, the user might consider whether possible multipliers could be seen as some more parameters which could be included in the balance function itself, their influence being adapted by influence weights.

14.4 Function Points

14.4.1 Short Description

A function point [16, 67] is an element of a DP program, defined by certain rules. The term function point has been developed in the late seventies by Allen J. Albrecht with IBM and apparently published for the first time in 1979 [67]. The number of function points of a program – like the number of instructions to be executed with COCOMO – is a suitable parameter for effort estimation.

The function point method additionally implies a simple regression analysis using the logarithmized goal “project effort” and the likewise logarithmized parameter “number of function points”. The group of authors of the method description used here [14] explains how to find function points as well as how to do the regression analysis [18].

Function point application, however, is not limited to the kind of regression analysis described there. Function points can be used separately as parameters.

With the function point method, the balance function resulting from regression analysis will be re-transformed and displayed grafically as a curved line [22]. A “productivity” characteristic of software development is central to the evaluations.

Because of the re-transformation, the distribution of actual project values around the curve is not exactly the same as the distribution with regression analysis, but stretched towards the top [27]. Similar distortions that are impossible to avoid exist with the planning chart, too (Sect. 12.4), and have to be put up with in practical applications.

The general formula of the curve is [19]

$$FP = a \times (MM)^b ,$$

where

FP = number of function points determined,

MM = number of man-months needed

a and b = coefficients (see Sect. 14.4.2).

The balance function can be seen by taking the logarithm of this curve formula; it reads

$$\log FP = \log a + b \times \log MM .$$

According to the explanation mentioned above, the function point method is a purely regression analytical method. Determining the number of function points of a program can be adapted, by means of rating tables, to the task at hand and the circumstances [17], but this is part of the parameter definition and not an interference with regression analysis results.

That establishing the curve is not a singular act but that new projects should be included continuously, as the authors note [23], underlines the transparent concept of this method, allowing current error estimation. Insofar I prefer it to COCOMO for the purpose of project comparisons, also those between companies.

Project comparisons, also across companies, already have been established in the IT sector [11], aided by specialized software [12, 67]. Continuously growing project files should result in growing stability and distinction of comparison results.

14.4.2 Inverse Calculation

You may have noted that goal (MM) and parameter (FP) have been swapped in comparison with similar other formulas, e.g., the basic equations of COCOMO or the Parametric Project Model. This swapping also appears in the charts of the curve and in the regression analysis of the function point method.

This creates the impression that basically the number of function points is determined by project effort, the latter being causally independent from the number of function points. This may be correct in some practical cases, but it is unusual as a calculation principle.

This swapping of variables, originating maybe from the course of development of the function point method, leads to somewhat different results than the calculation method discussed so far. For that reason, in the considerations to follow, we will indicate the calculation with swapped variables as “inverse”, the calculation method of the Parametric Project Model discussed so far as “normal” calculation conforming to the model.

To begin with, in the inverse balance function given in the preceding section

$$\log FP = \log a + b \times \log MM ,$$

$\log a$ is an inverse block value and b an inverse influence weight, both different from the corresponding normal quantities. Accordingly, there is an inverse scatter value, which can be found in the explanation mentioned above only in a re-transformed shape [21].

The inverse balance function is not identical to the normal balance function. I would like to demonstrate this fact experimentally, because it is important:

The group of authors has given the formula for calculating the curve for 12 of the projects documented in the publication mentioned [20] and shown a rough chart [21]. The formula reads

$$FP = 25.68 \times (MM)^{0.775} .$$

Taking the logarithm, as mentioned above, we get the inverse balance function of these projects (apart from rounding issues not relevant in this context)

$$\begin{aligned}\log \text{FP} &= \log 25.68 + 0.775 \times \log \text{MM} \\ &= 1.41 + 0.775 \times \log \text{MM} .\end{aligned}$$

Here, the dependent variable is $\log \text{FP}$, the independent variable is $\log \text{MM}$. As a first step of the experiment, I have confirmed this balance function by doing a regression analysis of the data published.

Arranging this equation in the way of a normal calculation, we get a seemingly normal balance function

$$\log \text{MM} = \frac{-1.41 + \log \text{FP}}{0.775}$$

or

$$\log \text{MM} = -1.82 + 1.29 \times \log \text{FP} .$$

Although the equation looks different, its values still correspond to the calculation from the dependent variable $\log \text{FP}$ and the independent variable $\log \text{MM}$; therefore the term “seemingly normal”.

Then I undertook one more regression analysis to be compared with this seemingly normal balance function, with the same published data, but using $\log \text{FP}$ and $\log \text{MM}$ the other way round. Now $\log \text{MM}$ was being used as dependent, $\log \text{FP}$ as independent variable.

Doing this, I took away the goal/parameter swapping and determined a really normal balance function. The result was

$$\log \text{MM} = -1.45 + 1.17 \times \log \text{FP} .$$

Now we can see that those last two equations, the seemingly normal balance function and the really normal one, do not coincide when checked in this way. Inverse calculation and normal calculation did not result in the same balance function.

Thus we have proved experimentally that inverse and normal balance function will not coincide.

This is not even difficult to understand. In a normal calculation chart, e.g., Fig. 8.1, the scatter value is the vertical difference between y and \hat{y} , i.e., the vertical distance of the observed point to the balance function. The inverse scatter value, however, in this chart would correspond to the lateral difference, i.e., the horizontal distance of the observed point from the balance function, setting aside the changes in the balance function involved.

Vertical and horizontal distance are related, but not in a way that would lead to the same balance function. For example, looking at a house from the front and from one side, we will get different views, although the house itself remains the same.

One more difference between normal and inverse calculation would crop up when preparing characteristics of the Project Goodness kind:

Dividing an inverse scatter value by the standard deviation and adding the scale constant 5, we would get not a Difficulty, but a declination, Difficulty being a goal property, not a parameter property, and having a different value to the declination mentioned. Calculation of Goodness would not be possible anyway, neither would calculation of Keeping.

However, we do not want to dwell on this method, as inverse calculation will not come up often outside the function point method and only serves to illustrate this method here.

14.4.3 Supplementing Inverse Calculation by Normal Calculation

Anyone just applying the methods only has to be aware that the characteristics system of Project Goodness and the function point method will result in intrinsically different characteristics and results, independent from their names. This is a logical consequence of their different regression approaches.

The results of these two approaches must not be confused, because this would cause misunderstandings, calculation errors and evaluation errors. Therefore using different terms in the two approaches – apart from a and b , which otherwise have varying mathematical meaning, too – is a good thing and should remain that way.

Whoever wants to have a deeper look into these two regression approaches has to remember the following:

- $\log a$ is an inverse block value in the function point method
- b is an inverse influence weight in the function point method
- the function point curve does not give Difficulty, Keeping, or Goodness characteristics, even when logarithmized,
- but in normal calculation giving these characteristics, function points can be used as parameters without restriction.

Given these distinctions and the understanding of relationships, both regression approaches can be used side by side with software projects, hereby enabling the user to calculate the function point method curve as well as the Project Goodness characteristics.

Chapter 15

A Software Tool for Simple Project Comparisons

In 2002, the expert group “Project Comparison Technique” (German: “Projektvergleichstechnik”) of the GPM Deutsche Gesellschaft fuer Projektmanagement e.V. published a software tool for simple project comparisons named “COMPAR” on the internet [32, 97].

COMPAR and associated instructions in German, English, and French [33–35] can be downloaded at

www.gpm-ipma.de
Know-how
Fach- und Projektgruppen
Projektvergleichstechnik

COMPAR has been developed for easy and limited application of Project Comparison Technique in benchmarking and is based on the well-known spreadsheet program Microsoft EXCEL. COMPARE uses the EXCEL regression function mentioned in Sect. 8.1. Using COMPARE, customers only have to be familiar with project management and MS EXCEL and have to be equipped with the necessary data of finished projects.

COMPAR allows up to four Base-Goals, four associated Check-Goals, the corresponding eight goal weights, and up to ten parameters, with a maximum of five per goal. All Difficulty, Keeping, and Goodness characteristics will be calculated.

COMPAR contains some data completely calculated as an example, a spreadsheet prepared for the customer’s use, and a template for inserting similar sheets. Technical and mathematical relationships are minimized and conveyed in a simple international form in the instructions in order to facilitate orientation. Theoretical considerations have been left out almost entirely.

Chapter 16

Approaching Success Characteristics

16.1 Binary Objectives and Quasi-Objectives

In Sect. 5.3, we mentioned that aside from calculating Project Goodness, also considering comparisons of actual against planned values, Satisfaction, and other quantities can contribute to project evaluation. To account for this, we have to expand our objective notions by adding binary objectives and quasi-objectives.

I will call binary those subobjectives of projects that, contrary to the subobjectives considered so far, do not possess a quantitative scaling, but only two possible results that are mutually exclusive: “subobjective attained” or “subobjective not attained”. As a small everyday example: going to an important conference, reaching or missing one’s train or plane is decisive. If we fail to show up in time, it is not important whether we have missed our transport only by seconds or by hours.

Similarly, but with more far-reaching consequences, with a space project, a successful rocket start is imperative. With an expedition to the North Pole or the South Pole, having reached the actual pole is a measure of success, the running of the project as a whole being of less concern.

Also with usual quantitative Check-Goals, in addition to measuring better or worse Keeping, we often want to evaluate in a binary way whether a desired value has been reached or not. In the section to follow, we will consider possible evaluation of binary objectives and of Check-Goals taken as being binary.

Afterwards, we will consider project criteria, e.g., Satisfaction, that are not mentioned or fixed quantitatively in the project objective description, but nevertheless contribute to evaluating the project. We will call them quasi-objectives of the project.

Contrary to formal subobjectives defined in the project objective description, quasi-objectives are not fixed by any contract. Because of this softness in terms, binarity is not relevant here. In Sects. 16.3 up to 16.5, we will consider such quasi-objectives that can be represented by goals to be chosen and can have different quantitative values, similar to subobjectives of the formal objective structure. Primarily, these are stakeholder satisfaction and project consequences.

Whenever binary objectives and/or quasi-objectives are supposed to be integrated in characteristics, they have to get goal weights before starting the project, which

have to be communicated, at least to the project team. Here, too, goal weights are strategic requirements for running the project.

16.2 Taking Account of Binariness

A binary objective can refer to cost, time, object, or quality requirements of the project, but it does not allow for quantitative scaling. For this reason, we cannot deal with a binary objective by the Partial Comparison method.

With Check-Goals being investigated by Partial Comparisons, at the same time binary evaluations may be desirable that can not be supplied by a Partial Comparison, as mentioned in Sect. 5.3. All the same, we can evaluate binary objectives and binary properties of Check-Goals.

We can adopt binary evaluations by imitating a Partial Comparison result. We assign a

Bi-Value (binary value) B

to the event of achieving or not achieving the binary objective. This value has to correspond to the relative frequency of achieving or not achieving the objective and also to the idea of normal distribution, as shown in Fig. 8.5.

A Bi-Value is an evaluation of the binary result and must not be confused with a binary number as representing one of the events of a binary system. In a Total Comparison, Bi-Values stand side by side with the Difficulty and Keeping characteristics from Partial Comparisons, thus expanding the Total Comparison concept.

Determining Bi-Values, we conveniently start by fixing the less frequent of the two possible results, regardless of its meaning that the corresponding binary objective has been attained or not; starting with the more frequent event may involve more exact calculations. So Fig. 16.1 can be used to determine the Bi-Value of the less frequent result. Temporarily, we will call this Bi-Value B_1 .

Relative Frequency of Less Frequent Result	Bi-Value of Less Frequent Result: The Binary Objective has been	
	Reached	Not Reached
0.001	8.0	2.0
0.006	7.5	2.5
0.023	7.0	3.0
0.067	6.5	3.5
0.159	6.0	4.0
0.309	5.5	4.5
0.421	5.2	4.8
0.500	5.0	5.0

Fig. 16.1 Bi-Values of the less frequent binary result (Bi-Values B_1)

For example, comparing 25 projects where a certain binary objective has been attained by 4 of the projects and has not been attained by 21 of the projects, reaching the binary objective has a relative frequency of $4/25 = 0.16$ and is the less frequent result, as the event of not reaching the binary objective happens 21 times, i.e. more frequently.

In a first step, we look up the probability of realization nearest to the relative frequency of 0.16 in the left column of Fig. 16.1. This is the value 0.159. Then we take the corresponding Bi-Value $B_1 = 6.0$ out of the column for reaching the binary objective. We assign this constant value of 6.0 to each one of the 4 projects that have attained the binary objective.

In a second step, we have to determine the Bi-Value B_2 for the more frequent binary result, in our example for the remaining 21 projects. Its value follows from the requirement that the sum of the Bi-Values of all projects in the comparison has to lead to a mean of 5, same as with a Partial Comparison.

Let n be the number of projects participating in the comparison and n'' the number of Bi-Values B_1 , then $n - n''$ is the number of Bi-Values B_2 . The requirement mentioned can be written as

$$B_1 n'' + B_2 (n - n'') = 5n .$$

This gives

$$B_2 = \frac{5n - B_1 n''}{n - n''} .$$

In our example of 25 projects with 4 having been assigned the Bi-Value $B_1 = 6.0$, the Bi-Value B_2 of the remaining 21 projects is

$$B_2 = \frac{5 \times 25 - 6 \times 4}{25 - 4} = 4.81 .$$

We assign this constant value of 4.81 to each one of the 21 projects that have not reached the binary objective. Now we have finished assigning the Bi-Values, and it is not important to differentiate between B_1 and B_2 any more.

The precision of Fig. 16.1 should be sufficient for most of the usual applications. If necessary, you can derive tables with intermediate grading of Bi-Values B_1 from the standard normal distribution function mentioned in Sect. 8.5 [41].

Of course, Bi-Values must not be mixed up with Difficulty and Keeping as they correspond to a different way of looking at objectives. They can, however, be calculated for all subobjectives of a project, too. We will call

B_K	Bi-Value of the cost objective	(KB)
B_T	Bi-Value of the time objective	(TB)
B_O	Bi-Value of the object objective	(OB)
B_Q	Bi-Value of the quality objective	(QB)

When weighting the objectives, Bi-Values also are handled similarly to Difficulty or Keeping:

W_{B_K}	Goal weight of Bi-Value of cost objective	(WKB)
W_{B_T}	Goal weight of Bi-Value of time objective	(WTB)
W_{B_O}	Goal weight of Bi-Value of object objective	(WOB)
W_{B_Q}	Goal weight of Bi-Value of quality objective	(WQB)

From the weighted Bi-Values, we form weighted means, as with Difficulty and Keeping; for example,

Bi-Value of the project objective

$$B_P = \frac{B_K \times W_{B_K} + B_T \times W_{B_T} + B_O \times W_{B_O} + B_Q \times W_{B_Q}}{W_{B_K} + W_{B_T} + W_{B_O} + W_{B_Q}}$$

Similarly, Bi-Values of process objective and performance objective can be calculated from B_K and B_T and from B_O and B_Q , respectively, together with their respective goal weights.

Binary problems in projects often will have consequences for the general goals of the Partial Comparisons, i.e., in Project Goodness, too. Not fulfilling important contracts will cause loss of time, contract penalties, or legal expenses; missing an important non-negotiable deadline will lead to replanning of object or quality objectives, schedule changes and additional costs, etc.

Including Bi-Values and their goal weights in a Total Comparison, also binary problems are registered, weighted, and evaluated. This will result in more far-reaching analyses and higher order characteristics than Goodness; first of all, attainment of objective, see Fig. 5.3. It will be symbolized by the letter Z. During the sections to follow, we will consider some more elements of extended project evaluation that will be connected and summarized in Sect. 16.6.

16.3 Taking Account of Stakeholder Satisfaction

Satisfaction being a “soft” criterion, it eludes a strict and contractible measurement and therefore a formal objective structure. Thus, project stakeholder Satisfaction is a quasi-objective. For our purposes, Satisfaction must not represent the emotional reaction to the facts contained in different goals, but a criterion of its own right, expressing social and communicational elements of the project, e.g., working atmosphere [96].

Following the Project Excellence model [30], we will distinguish between

customer or client satisfaction,
staff satisfaction, and
third party satisfaction.

Project values of these three quasi-objectives may be collected by scaled interviews [29], but also by different methods. The scaling may be chosen arbitrarily as the data will be linearized anyway; it may even differ between quasi-objectives. It only has to be uniform for all projects of a comparison for one quasi-objective, and the interview has to be aimed at the social elements of the project mentioned above.

We might decompose each one of these quasi-objectives into a Base-Goal and a Check-Goal (together with their corresponding goal weights). As each one of the quasi-objectives has to be collected uniformly throughout the projects to be compared, it would be formally possible to specify and check Satisfaction values to be attained during the project as well. But a specification and checking of this kind would be dubious and scarcely meaningful.

Therefore, we want to assume collection of the data after the project has been finished, i.e., final values, and confine ourselves to dealing with Base-Goals of Satisfaction. In order to avoid misunderstandings as to corresponding Check-Goals, we will call these Base-Goals simply goals.

Supposing that we already have defined the eight goals of the Basic Objective Structure as Y_1 to Y_8 , we can further define

Y_9	goal of customer satisfaction,
Y_{10}	goal of staff satisfaction,
Y_{11}	goal of third party satisfaction.

The target variables derived from these goals will be submitted to usual Partial Comparisons with or without parameters; here, modal parameters of the form of project management may be more important than natural parameters.

Using only Base-Goals and not Check-Goals, the Partial Comparisons will yield only “Satisfaction Difficulty” values. As the complement “Satisfaction Keeping” is missing, this “Difficulty” will be called a declination according to Sect. 13.6:

H_1	declination of customer satisfaction,
H_2	declination of staff satisfaction,
H_3	declination of third party satisfaction.

The symbol H has been chosen not for linguistic reasons, but in order to avoid symbols already used for other terms. Declinations will be expressed by values between 0 and 10 because of their calculation, same as Difficulty and Keeping. To each one of these characteristics, i.e., its corresponding goal, we will assign a goal weight when starting the project:

W_{H_1}	goal weight of customer satisfaction,
W_{H_2}	goal weight of staff satisfaction,
W_{H_3}	goal weight of third party satisfaction.

As usual, the three weighted characteristics enable us to calculate the weighted mean:

$$\text{Project or Overall Satisfaction } H_p = \frac{H_1 \times W_{H_1} + H_2 \times W_{H_2} + H_3 \times W_{H_3}}{W_{H_1} + W_{H_2} + W_{H_3}}$$

16.4 Taking Account of the Form of Project Management

With the form of project management (cf. Fig. 5.3) and its elements, the situation is less clear [30, 31]. Good project management is the best way to get good project results; but depending on the point of view, scaling forms of project management or some of its elements [30, 31] may yield parameters and/or goals.

Evaluating only Project Goodness, Objective Attainment, Project Management Success, or Project Success, the form of project management stands outside the system of evaluated objectives and quasi-objectives, cf. Fig. 5.3. The form of project management therefore yields parameters, i.e., more specifically, modal parameters. In Sect. 13.2, we have already made use of one detail of the form of project management, degree of scheduling, as a modal parameter.

Form of project management may become a quasi-objective if a project is aimed at extraordinary project excellence or if the customer desires maximization or minimization of a scalable project management characteristic, e.g., frequency of reports or conferences. If data from a sufficient number of similar projects are available, we can investigate, at least partially, the form of project management as a goal.

We should take care not to confuse project management characteristics taken as a quasi-objective of a project with projects specifically aimed at introducing or improving project management in an organization. Of course, with such a project, realization of a certain form of project management is a primary part of the Performance Objective, i.e., an element of the formal objective structure.

With other projects, only viewing the actual comparison we can decide whether to take parts of the form of project management as a quasi-objective. In the perspective of this chapter, centered on success characteristics, we want to look at the form of project management only as a source of possible parameters.

16.5 Taking Account of the Project Consequences

Project Consequences basically mean the effects of the project that can be felt after the project has been finished, e.g., ecological, economical, sociological, and technological consequences (Fig. 5.3). The Project Consequences may be intended by the organization realizing the project, but they also may occur surprisingly and some time after the project has been finished, e.g., caused by some other events happening [96].

The economic project consequences, being intended in most cases, usually are being estimated at early stages, as they are decisive for the project being cost-effective. Examples are the payback period of the money invested in a project or the long-term financial gain.

Other project consequences may arise in different and remote areas and may be difficult to be recognized or identified. Often, however, – e.g., with big-scale public traffic projects, – project consequences are being estimated in the best way possible, involving more than the economic part.

For the sake of our considerations, we want to assume that scaled data series of goals for the four possible consequences exemplified above are available, similar to those of Satisfaction:

Y_{12}	goal of ecological consequences,
Y_{13}	goal of economical consequences,
Y_{14}	goal of sociological consequences,
Y_{15}	goal of technical and/or technological consequences of the project.

Here, we have simplified the structure in the same way as with Satisfaction, without decomposition into Base-Goals and Check-Goals. Of course, you may add or structure further goals.

The goals chosen have to be different from those of the formal objective structure as well as from those of other quasi-objectives, e.g. Satisfaction. This holds even in cases where Project Consequences are recorded based on interviews registering the satisfaction of persons affected by the project.

If need be, we must differentiate between

- goals $Y(H)$ of satisfaction with the social and communicative manner of running the project, and
- goals $Y(F)$ of satisfaction with the project consequences (let F be the symbol for the Project Consequences characteristic)

The goals $Y(F)$ have to be assigned to the project consequences, anyway, in order to avoid undesired mixing between Project Success and Project Management Success.

Apart from this, there is a serious difference between Project Consequences and other evaluation criteria of projects: the actual project consequences can not be definitely stated when or immediately after the project has been finished. This difficulty, an exception for the formal objective structure, is a normal event with project consequences.

In some cases, e.g. with reservoir construction or large-scale industrial zone construction projects, project consequences only become apparent with the passing of time. Also, interpretation of project consequences may vary over the years, given different political viewpoints and different circumstances.

For important cases, several evaluations of project consequences may be taken: one at project start and project finish, respectively, one some years later, and one

perhaps some decades later. The symbol l for the project status we used in Sects. 8.6 and 8.7 to distinguish initial and final project values here gets further implementations that possibly go far beyond the project finish and characterize values with the same time interval to the project finish.

Because of this dependence on long-term development and this classification difficulty, we will treat Project Consequences as quasi-objectives. If such criteria are subobjectives included in the formal objective structure, they must not additionally appear as quasi-objectives. Quasi-objectives only are those consequences that are not included in any formal project objective but nevertheless contribute to the Project Success.

Doing Partial Comparisons with the goals chosen, we get, simplified similarly to the situation with Satisfaction, the following characteristics:

F_1	declination of ecological consequences,
F_2	declination of economical consequences,
F_3	declination of sociological consequences,
F_4	declination of technical and /or technological consequences.

Each goal, or each characteristic, will be assigned a goal weight:

W_{F_1}	goal weight of ecological consequences,
W_{F_2}	goal weight of economical consequences,
W_{F_3}	goal weight of sociological consequences,
W_{F_4}	goal weight of technical or technological consequences.

Here, too, we calculate the higher-order characteristic “Project Consequences” as a weighted mean:

$$\text{Project Consequences } F_P = \frac{F_1 \times W_{F_1} + F_2 \times W_{F_2} + F_3 \times W_{F_3} + F_4 \times W_{F_4}}{W_{F_1} + W_{F_2} + W_{F_3} + W_{F_4}}.$$

16.6 Total Comparison, Including the New Criteria

Putting together the eight assumed weighted basic characteristics of Project Goodness and the weighted basic characteristics of Satisfaction, Project Consequences and weighted Bi-Values to form weighted means, we get the characteristic structure shown in Fig. 16.2. The notion of Total Comparison has been further expanded compared to the definition of Sect. 5.1.1 by including Bi-Values.

Beyond Project Goodness, Fig. 16.2 shows the following characteristics: Project Objective Attainment (PZ), Project Management Success (PJ) and Project Success (PN). The symbols PJ and PN again are not chosen for linguistic reasons, but

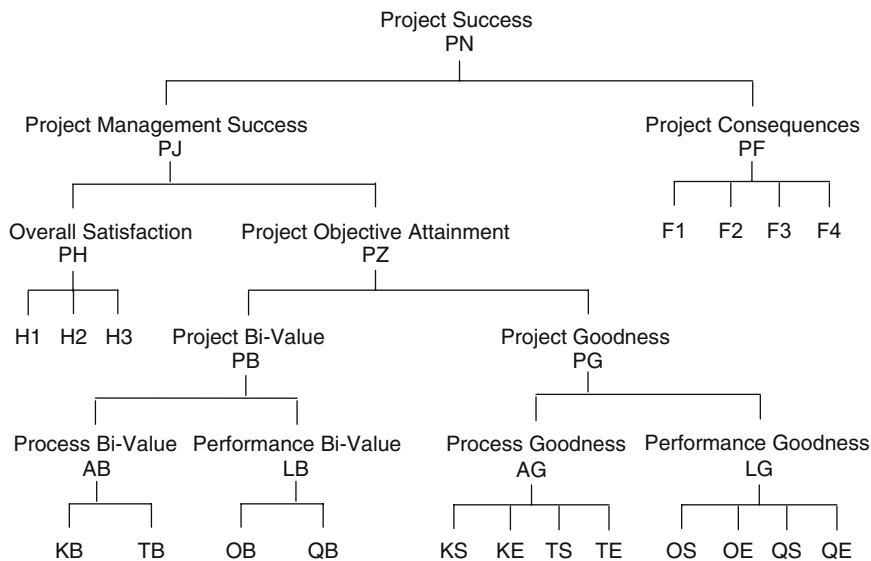


Fig. 16.2 Structure of Project Objective Attainment, Project Management Success, and Project Success Characteristics (example)

to avoid letters already used for different notions. For the sake of succinctness, Fig. 16.2 shows only symbols in DP notation for base characteristics.

The Project Management Success of Fig. 16.2 corresponds to the notion of Project Results in the Project Excellence model (Fig. 5.3). Project Objective Attainment completely contains the formal objective structure and can be segmented into Process, Performance, Cost, Time, Object, and Quality Objective Attainment, similar to Difficulty, Keeping, Goodness, and Bi-Value. This is not possible for Project Management Success and Project Success, as stakeholder Satisfaction and Project Consequences have a different structure.

The characteristics in Fig. 16.2 are calculated in the same way as before, as weighted means of the respective weighted base characteristics or ratings. We will list only the three topmost new characteristics in DP notation and without giving the long formula explicitly, as the rule for establishing the formula is simple and has been shown repeatedly throughout the text so far:

Project Objective Attainment: Weighted mean of the characteristics
KB, TB, OB, QB, KS, KE, TS, TE, OS, OE, QS, and QE.

Project Management Success: Weighted mean of the characteristics
H1, H2, H3, KB, TB, OB, QB, KS, KE, TS, TE, OS, OE, QS, and QE.

Project Success: Weighted mean of the characteristics
H1, H2, H3, KB, TB, OB, QB, KS, KE, TS, TE, OS, OE, QS, QE, F1, F2, F3, and F4.

Because of the often long times of waiting until project consequences can be evaluated seriously, if they can be identified at all, the Project Success characteristic is not qualified for quick comparisons shortly after the project finish. Additionally, it will be subject to major fluctuations caused by possible instability of goals and goal weights of the Project Consequences. The Project Success characteristic is valuable because of its model character, supporting discussion about objectives and theory-oriented comparisons.

This restriction, however, does not hold for the Project Objective Attainment and Project Management Success characteristics. These can be calculated shortly after the project finish, same as the Project Goodness characteristic, using goal values that need not be revised later on. Thus, these two characteristics are as well suited for everyday project work as the Project Goodness characteristic, if binary issues or the satisfaction of persons affected by the project are to be evaluated besides Project Goodness.

Table of Abbreviations

(Approximately Alphabetically Ordered by DP Notation)

Combinations of letters in DP notation do not denote the multiplication of corresponding quantities, but always an indivisible name of just one quantity. Whenever we multiply two quantities, usually the multiplication sign (\times or $*$, respectively) will be written explicitly.

Collected forms of goal weights will be characterized by adding the respective Bi-Value, Difficulty, or Keeping symbol of the corresponding subobjectives, because thus they can be given in generalized form without explicitly naming the binary objective, Base-Goal, or Check-Goal.

In an extended objective structure, where base characteristics are a weighted mean of two or more partial characteristics instead of the immediate result of a Partial Comparison, a grave accent ($\grave{}$) will be attached to their subobjective symbol of K, O, Q, or T. The partial Bi-Value, Difficulty, or Keeping characteristics will be distinguished by attaching numbers in the same place (cf. Sect. 5.1.2).

The letter *l* will be printed in italics where necessary to avoid confusion with the number 1.

	Math.	DP
Process Bi-Value	B_A	AB
Process Keeping	E_A	AE
Process Goodness	G_A	AG
Process Difficulty	S_A	AS
Process Objective Attainment	Z_A	AZ
Bi-Value	B	B
Declination (if not named differently)	(D)	(D)
Coefficient of determination	Deter	Deter
Declination of Project Consequences	F	F
Final	ε	final
Final comparison	FinalCo	FinalCo
Ratio (quotient) of final and initial value	FIQ	FIQ
Goodness	G	G
Declination of Satisfaction	H	H
Index	I	I
Index with changed base	I'	I'
Value of original index in the year of base change	I_c	I_c
Cost index, price index, or working-time index q ($q = 1, 2, 3, \dots$)	I_q	I_q

	Math.	DP
Initial	α	initial
Initial comparison	InitialCo	InitialCo
Cost Bi-Value	B_K	KB
Cost Keeping	E_K	KE
Cost Goodness	G_K	KG
Cost Difficulty	S_K	KS
Cost Objective Attainment	Z_K	KZ
Performance Bi-Value	B_L	LB
Performance Keeping	E_L	LE
Performance Goodness	G_L	LG
Performance Difficulty	S_L	LS
Performance Objective Attainment	Z_L	LZ
Object Bi-Value	B_O	OB
Object Keeping	E_O	OE
Object Goodness	G_O	OG
Object Difficulty	S_O	OS
Object Objective Attainment	Z_O	OZ
Project i or d, respectively (i = sequential number in a Partial Comparison, e.g., P_1, P_2, P_3 , etc.;	P_i	Pd
d = sequential number for time of collection, e.g., P001, P002, P003, etc.)		
Parametric Project Model	P'	P'
Project Bi-Value	B_P	PB
Project Keeping	E_P	PE
Weighted mean of Project Consequences Declinations	F_P	PF
Project Goodness	G_P	PG
Project or overall Satisfaction	H_P	PH
Project Management Success	J_P	PJ
Project Management	–	PM
Project Success	N_P	PN
Project Difficulty	S_P	PS
Project Objective Attainment	Z_P	PZ
Quality Bi-Value	B_Q	QB
Quality Keeping	E_Q	QE
Quality Goodness	G_Q	QG
Quality Difficulty	S_Q	QS
Quality Objective Attainment	Z_Q	QZ
Empirical realization probability	Rea	Rea
Significance	Signi	Signi
Standard deviation of scatter values of a Partial Comparison	s	StDev
Time Bi-Value	B_T	TB
Time Keeping	E_T	TE
Time Goodness	G_T	TG
Time Difficulty	S_T	TS
Time Objective Attainment	Z_T	TZ
Type 2 comparison (same for other type numbers)	Type2Co	Type2Co
Bi-Value of any lowest-level subobjective U	B_U	UB
Keeping of any lowest-level subobjective U	E_U	UE
Difficulty of any lowest-level subobjective U	S_U	US
Goal weight of the Bi-Value of subobjective U	W_{B_U}	WUB
Goal weight of the Check-Goal of subobjective U	W_{E_U}	WUE
Goal weight of the Base-Goal of subobjective U	W_{S_U}	WUS
Influence (variable)	x	x

	Math.	DP
Collected form j or d, resp., of project values of parameters (j = sequential number of influences x or parameters X of a Partial Comparison; e.g., X ₁ , X ₂ , X ₃ etc.;	X _j	Xd
d = sequential number of the chronological or technical order of the collected forms X in files, e.g., X001, X002, X003 etc.)		
Unspecified influence variable j or d, respectively	X _j '	Xd'
X _j or Xd, respectively, to the power of r	X _j ^r	Xd**r
Reciprocal of X _j or Xd, respectively	1/X _j	1/Xd
Collected form k or d, respectively, of project values of goals (k = sequential number of targets y or goals Y of a Total Comparison; e.g., Y ₁ , Y ₂ , Y ₃ etc.	Y _k	Yd
d = sequential number of the chronological or technical order of the collected forms Y in files, e.g., Y001, Y002, Y003 etc.)		
Unspecified target variable k or d, respectively	Y _k '	Yd'
Balance function of target y _k =Y _k or Yd, respectively	ŷ _k , y=Y	Yd [^]
Balance function of target y _k =ln(Y _k) or ln(Yd), respectively	ŷ _k , y=ln Y	lnYd [^]
Balance function of target y _k =√Y _k or sqrt(Yd), respectively	ŷ _k , y=√Y	sqrtYd [^]
Multiplication sign	×	*
Summation sign	∑	–
Block value (intercept) of a Partial Comparison	a	a
Influence weight (regression coefficient) of influences or independent variables in simple regression	b	b
Influence weight (regression coefficient) of influences or independent variables in multiple regression	b _j	b _j
Documentation number of a project or a collected form in files	–	d
Exponential function with base e	exp	exp
Unspecified mathematical function	f	f
Scatter value of a project (difference in height, residual);	h	h
in Sect. 3.4 only: Scatter value measured	h _g	–
Sign-adjusted scatter value	h'	h'
in Sect. 3.5.2 only: Mean of adjusted scatter values	h' _M	–
Sequential number of a project in a Partial Comparison	i	–
Sequential number of an influence variable in a Partial Comparison (also number of an independent variable)	j	j
Sequential number of a target variable in a Partial Comparison; in Sect. 8.7 only:	k	–
Sequential numbers of Difficulty characteristics	k'	–
Sequential number of a specific Difficulty characteristic	k''	–
Reference date of a Partial Comparison during the running of a project	l	l
Natural logarithm	ln	ln
Label of Total Comparisons (m may be a compound)	m	m
Number of projects of a Partial Comparison	n	n
Number of ranks of a Partial Comparison	n'	n'
Number of Bi-Values B ₁ of one binary comparison	n''	n''
Number of influence variables of a Partial Comparison (also number of independent variables)	p	p

	Math.	DP
Square root	$\sqrt{\quad}$	sqrt
Independent variable(s), influence (variable)	x	x
Values of any influence variable, from parameters and quasi-parameters (also values of independent variables)	x	x
Dependent variable, target (variable)	y	y
Values of any target variable (also values of dependent variables)	y	y
Number of target variables of a Total Comparison (also number of dependent variables)	z	z

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List of Figures

- 2.1 Basic Objective Structure 12
- 2.2 Overall objective and subobjectives 13
- 2.3 Example of an expanded objective structure 13
- 2.4 Symbolic decomposition of lowest-level subobjectives 16
- 2.5 Realistic decomposition of lowest-level subobjectives, shown by
costobjective and time objective 17
- 2.6 Goals and goal weights of lowest-level subobjectives 17
- 2.7 Structure of a lowest-level time objective (example) 18
- 3.1 Example for Partial Comparison 24
- 3.2 Balance line between final project duration and final number of parts
of the example 24
- 3.3 Project duration scatter values for the example 25
- 3.4 Error estimation for Fig. 3.3 25
- 3.5 Values and means of sign-adjusted scatter values for project duration
and project costs of the example 27
- 3.6 Results of two Partial Comparisons for the example 29
- 3.7 Partial Comparison of a Check-Goal, here: excess project duration;
o = example project 30
- 3.8 Calculating the adjusted scatter values for a Partial Comparison
without parameters (example) 31
- 5.1 Structure for Difficulty and Keeping for the Basic Objective Structure . 37
- 5.2 Goodness characteristics structure out of the unweighted Difficulty
and Keeping characteristics for the Basic Objective Structure 40
- 5.3 Integration of Project Goodness in the concept of Project Excellence
and Project Success 42
- 6.1 Data combination types of comparisons 43
- 6.2 Symbolic illustration of some comparison types 45
- 6.3 Overview of types 50
- 8.1 Decomposition of an observed value \hat{y}_i into guide value \hat{y}_i and scatter
value h_i 57
- 8.2 Influence separation in regression analysis 59
- 8.3 Idealized scattering of a linear relationship 62

8.4	Result plot of a Partial Comparison	63
8.5	Realization probability of certain values of Difficulty S or Keeping E, respectively, from Partial Comparisons, under the condition of normally distributed scatter values	65
9.1	Important interconnections during a project	78
10.1	Examples of primary variables (different use of X)	83
10.2	Examples of derived variables (different use of Y)	84
10.3	Examples of activity variables (different use of X and Y)	84
10.4	Indices used for price, cost, and working-time correction; the variables X096 and X097 mentioned with index 4 are to be understood the same way as the variables X018A and X024 mentioned with index 3 . .	85
10.5	Data collecting sheet 1	86
10.6	Data collecting sheet 2+3	87
10.7	Data collecting sheet 4	88
10.8	Example for a reference list of the degree of innovation	89
10.9	Example for a reference list of the number of different parts	90
10.10	Collection-oriented data presentation	91
10.11	Process-oriented data presentation	91
11.1	Result plot of the Cost Difficulty of the example	98
11.2	Result plot of the Time Difficulty of the example	99
11.3	Result plot of the Object Difficulty of the example	100
11.4	Result plot of the Quality Difficulty of the example	101
11.5	Result plot of the Cost Keeping of the example	102
11.6	Result plot of the Time Keeping of the example	103
12.1	Final comparison table	110
12.2	Initial comparison table	111
12.3	Final star chart	113
12.4	Initial star chartstar chart	113
12.5	Combined star chartcombined star chartstar chart	114
12.6	Planning chart	115
12.7	Projects as bars and points on a time scale	117
12.8	Time series of Cost Difficulty of the 177 projects	118
12.9	Time series of Time Keeping of the 177 projects	119
12.10	Trend chart of Cost Difficulty of the 177 projects	120
12.11	Trend chart of Time Keeping of the 177 projects	120
12.12	Time series of supplemented Quality Keeping	121
12.13	Trend chart of supplemented Quality Keeping	121
12.14	Trend chart of Performance Goodness of the 177 projects	122
12.15	Trend chart of Project Goodness of the 177 projects	123
12.16	Trend chart of Project Difficulty of the 177 projects	123
12.17	Trend chart of Project Keeping of the 177 projects	124
13.1	Trend chart of Cost Difficulty with new balance function	129
13.2	Trend chart of Fig. 13.1 with a part of the new balance function (thin upper line)	129

13.3	Part of the “Provelle” for cameras, status date 1981-3-10	132
16.1	Bi-Values of the less frequent binary result (Bi-Values B1)	148
16.2	Structure of Project Objective Attainment, Project Management Success, and Project Success Characteristics (example)	155

Index

A

Abbreviation, 33–34, 51, 61, 63, 157
Abscissa, 24, 62, 115, 118
Activity, 14, 83–84, 132
Actual data, 7, 9
Additional production costs, 83, 101
Apostrophe, 26, 60, 69
Assumptions of the least squares method, 61
Attainment of objective, 42, 152, 154–155

B

Balance function, 30, 47–51, 55–56, 62, 65, 70–71, 82, 95, 98–103, 119, 126–129, 131, 137, 139–142
Balance line, 24–28, 30–31, 44, 56–58, 62, 118
Base change, 53, 157
Base-Goal, 12–16, 28, 29, 32, 34, 38, 48–49, 95–97, 104, 110, 132, 137–143, 145, 151, 153
Base-Target, 28–29, 36, 69
Basic Objective Structure, 11–13, 35–37, 69, 95, 151
Benchmark, 3, 145
Block value, 57, 59, 68, 71, 127, 128, 141, 143, 159

C

Calibration, 138, 139
Causality, 22–23, 31, 55, 64, 104–105, 134
Characteristic, 3–9, 16, 19, 24–26, 29–30, 32, 34–47, 49–51, 59, 64–67, 69–70, 91, 96, 104–105, 110, 112–116, 119, 124, 130–131, 134, 140, 143, 145, 147–156
Chart, 23, 62, 112–124, 128–130, 133, 140–142
Check-Goal, 12, 14–16, 30–32, 34, 48, 95, 97, 104, 110, 145, 147–148, 151, 153
Check-Target, 28, 36, 69
Coefficient of determination, 63–64, 104

Collected form, 19, 22, 25, 54, 61, 71, 82, 84, 92, 99
Collection stage, 85
Combined star chart, 114, 117
Comparison table, 7, 109–112, 130
Comparison type, 43–47, 49–50, 69–71
Correlation, 63
Cost, 3, 5, 8, 12–17, 19, 21, 27, 29, 34, 37–40, 44, 53, 54, 59, 71, 76, 78–79, 81–85, 95–96, 99–100, 101–102, 104, 113–114, 118, 120, 122, 129–132, 137–138, 148–150, 153, 155
 development, 14, 84, 101, 138
 estimation, 8, 83, 105
 index, 54
 objective, 12–13, 14–16, 34, 37, 149, 155
 of production tools, 101
Cost Difficulty, 16, 29, 34, 37–38, 98, 101, 113–114, 118, 120, 129, 158
Cost Goodness, 39, 40–41
Cost Keeping, 16, 29, 34, 38, 101–102, 113–114

D

Data, 3–8, 10, 19, 21, 23, 33, 42–44, 47, 54, 61, 67–68, 70, 75, 78, 81–93, 95, 97, 102, 105, 112, 117, 119, 126, 132–133, 137–139, 142, 145, 151–153
 base, 7, 61, 105, 132, 137–138
 collecting sheet, 86–89, 92
 collection, 10, 81–82, 89, 112
 combination, 4, 43–44
 empirical, 3, 5, 7
 error, 67, 92–93, 102
 keeping, 70
 planned, 8–9
 processing, 21, 33, 75, 79, 85, 90–91
Declination, 135, 143, 151, 154
Decomposition equation, 67–68, 134

- Defect rate, 95–97, 100, 104, 122
Degree of difficulty, 7–8, 17, 22, 28, 81, 132
Degree of innovation, 89, 97–103, 125, 127
Dependent variable, 55, 135, 142
Descriptive comparison, 47, 51, 56, 64, 104, 131
Development costs, 14, 83, 101, 138
Deviation, 8, 28–29, 31, 34, 48, 51, 57, 61, 63, 89, 143
Difficulty, 5, 7–8, 16–17, 19, 22, 28–29, 32, 34–40, 42, 44–51, 59, 61–62, 63–66, 69–70, 98–101, 112–114, 118
Documentation number, 33, 70, 82
Duration, 7, 14–18, 24–27, 29–33, 44, 52, 58–59, 78, 82, 84, 95–96, 99, 102–103, 115–117, 125–127, 132–133, 137, 139
- E**
Early warning indicators, 6
Effect, 6, 10, 22, 27, 50, 55–56, 59–60, 64, 66, 79, 97, 99, 104–105, 122, 124, 126–129, 152
Efficiency, 5, 14, 42
Effort estimation, 81, 126, 139–140
Empirical data, 3, 5, 7
Empirical realization probability, 66, 71, 112
Endogenous, 7–8, 16, 29, 81, 132
Exogenous, 7–8, 81, 132–134
Extended objective structure, 37, 41
- F**
File, 18, 51, 82–83, 141
 projects, of, 51, 82
 structure, 90–92
Final comparison, 6, 47, 50–52, 66, 71, 110–111, 113, 117–118, 124, 129
 table, 110–111
Final value, 9, 12, 19, 22, 24, 43–44, 46–48, 50, 52, 67–68, 70, 112, 116, 119
Finish, 15, 17, 70, 77, 84–87, 97, 112–118, 132–133, 138, 151–152
Form of project management, 68, 151–152
Function point, 22, 137, 140–143
- G**
Goal, 14, 17–19, 23, 31, 45, 59–60, 64, 68, 82, 105, 127–128, 140–142, 145, 151–152, 154–156
 form, 23, 51, 60, 64, 134
 weight, 7, 12, 17–18, 22, 27, 34–35, 38, 43, 45, 56, 59, 70, 95–97, 110, 113, 122, 126, 150–151, 154
- Goodness, 3, 8, 38–42, 44, 68, 115, 117, 122–124, 130–131, 135, 143, 145–147, 150, 152, 154–156
Grave accent, 37
Guide value, 8, 24–28, 30–31, 45, 48–50, 56–57, 63, 98–99, 101–102, 116, 118, 128
- H**
Hat, 56, 70
- I**
Independent variable, 56, 135, 142
Index, 19, 53–54, 71, 83–85, 95–96, 98–103, 115
 correction, 54, 116
Inferential comparison, 47–48, 51, 104–105, 131
Inflation, 19, 54, 83
Influence variable, 23, 57–63, 69–71, 99–100, 103, 128, 134–135
Influence weight, 56–57, 59, 70, 99, 105, 130, 140–141, 143
Initial comparison, 47–51, 64, 66, 71, 111–117
 table, 110–111, 113
Initial value(s) 9, 12, 16–17, 43–44, 52, 70, 89, 96, 104, 112, 119
Inverse block value, 141, 143
Inverse calculation, 141–142
Inverse influence weight, 141, 143
Inverse scatter value, 141–142
IT projects, 3, 137
- K**
Keeping, 15–16, 21, 28–30, 32–36, 38–40, 42, 44, 48–49, 61–66, 68, 81, 96, 102–105, 112, 119, 124, 135, 143, 145, 148–151, 155
Knowledge management, 3, 8
- L**
Least squares method, 55–56, 58, 61, 139
Linearization, 68
Logarithm, 60, 71, 99, 140, 142
- M**
Mean, 27, 31, 38, 56–57, 62, 114, 130, 152, 154–155
Modal parameter, 22, 81, 127, 152
Model value, 23, 55, 69, 71, 115
Multiple regression, 58, 61–62
Multi-project management, 4

N

Natural parameter, 22, 97, 127, 151
 Network plan, 79, 81, 127, 132
 Nominal/actual value comparison, 41
 Nominal data, 9
 North Sea oil projects, 5
 Number of different parts of a product, 90

O

Object, 6–7, 12, 14, 17, 30, 34, 84, 125–126, 148–150
 Object Difficulty, 34, 37–38, 100, 113–114
 Object Goodness, 39–40
 Objective, 3, 5, 11–13, 16–18, 38–41, 81, 95, 97, 110, 134–135, 147–152
 structure, 11, 13, 33, 35, 40–42, 134–135, 147, 150–151, 153–155
 Objective Attainment, 41, 152, 154–156
 Object Keeping, 34, 37, 113–114
 Object objective, 12–13, 34, 149–150
 Octagon, 113
 Ordinate, 25, 56, 116
 Outlier, 62, 64, 66, 92, 102–103

P

Parameter, 7–8, 19–21, 26, 30–32, 45–46, 51, 55, 58–60, 63–64, 67, 69, 71, 81, 83, 89, 95, 97–98, 100, 105, 110, 125–128, 130–131, 134, 138–139, 141–143, 151–152
 form, 23, 51, 58, 60, 64, 83, 99, 134
 Partial Comparison, 21–32, 34, 36–37, 39–40, 46, 48, 55–58, 60–65, 67, 69–70, 71, 90–91, 95–97, 103–105, 119, 132, 137, 148–151, 154
 Performance, 13–15, 35–37, 39, 40, 42, 112, 122, 125, 150, 152, 155
 objective, 12–13, 15, 35, 150, 152
 Performance Difficulty, 35–37
 Performance Keeping, 35–37
 Planned data, 8, 9
 Planned finish date, 17, 115–116, 133
 Polar chart, 112
 Price index, 54, 95
 Primary variable, 82, 84
 Process, 6, 9, 12, 18, 21, 33, 35, 37, 49, 63, 67–68, 78–79, 81–93, 97, 112, 132, 150, 155
 design, 6, 42
 Process Difficulty, 35–37, 157
 Process Goodness, 40, 42, 155
 Process Keeping, 35–37

Process objective, 36–37, 150
 Process planning, 6, 21, 132
 Production costs, 14, 83–84, 88–88, 95–96, 99–100, 122, 126
 Prognosis method, 137–143
 Progress control, 132
 Project
 characteristic, 8, 113
 comparison, 3–4, 9, 10, 13, 14, 17–19, 27, 33, 42, 45, 53, 56, 66, 76, 83, 84, 85, 92, 95–97, 109, 112, 125–127, 130, 141, 145
 controlling, 3, 8, 132
 costs, 14–15, 18, 27, 29, 38, 44, 59, 78, 84, 95–96, 98, 101, 137
 duration, 14–18, 25–27, 29–32, 44, 52, 58–59, 78, 81, 84, 95–96, 99, 100, 103, 115–116, 132–133
 effort, 140–141
 evaluation, 8, 11, 14–16, 42, 130, 134, 147, 150
 excellence, 41–42, 150, 152, 155
 finish, 15, 78, 83, 87, 97, 115, 154, 156
 knowledge management, 3–4
 manager, 15, 18, 79, 127
 measurement, 4
 model, 68, 70
 objective, 6, 8, 11, 12–14, 18, 36, 49, 64, 112, 134, 147, 154–156
 planning, 4–5, 105
 start, 46, 116–117, 132–133, 153–154
 theory, 4, 9, 67
 type, 6
 value, 18, 22, 31, 59–60, 68, 70–71, 82, 92, 116, 140, 151, 154
 Project Comparison Technique, 3–5, 7–10, 53, 103, 134, 145
 Project Difficulty, 36–37, 42, 123
 Project Goodness, 3, 39–42, 115, 117, 122–124, 130–131, 143, 147, 150, 152, 154–156
 Project Keeping, 36–37, 42, 124
 Project Management Award, 5, 41
 Project Success, 41–42, 152–155

Q

Quality, 8, 12–14, 17, 34, 37–39, 78, 82, 88, 96–97, 110, 148–150
 Quality Difficulty, 34, 37, 101, 110, 113–114
 Quality Goodness, 39–41
 Quality Keeping, 34, 37, 44, 113, 121, 130
 Quasi-parameter, 23, 45–46, 59, 67, 69–70, 127, 134, 139

R

Ranking, 18–19, 30, 66
 Realization probability, 6, 44, 49, 64–66,
 71, 112
 Reciprocal, 54, 60, 85, 99
 Reference
 date, 43, 45, 70, 117–119
 list, 85, 89
 project, 48–49, 110
 Regression analysis, 8, 55, 57, 59, 61, 67, 81,
 131, 139–142
 Residual, 57, 62
 Result plot, 62–64, 95, 97, 101–102, 109, 128

S

Satisfaction, 42, 68, 147, 150–156
 Scale constant, 28, 48, 66, 143
 Scattering, 23, 55, 62, 98–104, 119, 128
 Scatter value, 24–28, 31–32, 34, 44, 55–59,
 61–62, 64–68, 96, 128, 135, 141–143
 Scheduling, 76, 79, 81, 83, 88, 90, 97, 105,
 116, 122, 125–128, 152
 Significance, 39, 57, 63–64, 104, 111, 119, 131
 Sign rule, 26
 Simple regression, 71, 140
 Singular projects, 5, 9
 Stability, 98, 104–105, 130–131, 139, 141
 Standard deviation, 27–28, 31, 34, 48, 61,
 63, 143
 Standardization, 79
 Star chart, 7, 112–114, 117, 130
 Start, 46, 48, 76–79, 82–84, 97, 112, 116, 126,
 132–133, 138, 147–148, 153
 Statistics, 10, 55–57, 65, 90, 104–105, 131

Subobjective, 11–17, 28–35, 37–38, 41, 45, 61,
 65, 81, 109–110, 112, 147, 149, 154

T

Target, 23–25, 27–28, 30, 43, 45, 48, 50,
 56–60, 62–65, 67–70, 71, 98, 103, 112,
 134–135, 151

Time

 objective, 12–17, 34, 38, 149–150
 series, 7, 53, 54, 96, 116–124
 Time Difficulty, 16–17, 29, 34, 37–38, 99,
 113–115

Time Goodness, 39–40

Time Keeping, 16–17, 34, 37, 102–103,
 113–114, 118–119, 122

Total Comparison, 19, 32, 35–42, 45, 51, 59,
 66, 67, 71, 95–105, 109, 118, 127, 130,
 135, 137, 148, 150, 154–156

Transformation, 23, 51, 60, 62, 64, 67–68, 92,
 116, 140

Trend

 analysis, 3–4, 7–8, 124
 chart, 119–120, 122, 124, 128–129

U

Unique project, 6, 68

V

Vertical distance, 142

W

Work breakdown structure, 11, 21
 Workflow organization, 75, 79
 Working-time index, 53, 54, 71

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