A Handbook for

Construction Planning and Scheduling

Andrew Baldwin
David Bordoli

WILEY Blackwell

A Handbook for Construction Planning and Scheduling

The book's companion website is at

www.wiley.com/go/baldwin/constructionplansched

You will find here freely downloadable support materials.

A Handbook for Construction Planning and Scheduling

Andrew Baldwin

and

David Bordoli

WILEY Blackwell

This edition first published 2014

Registered Office
John Wiley & Sons, Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial Offices
9600 Garsington Road, Oxford, OX4 2DQ, UK
The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at www.wiley.com/wiley-blackwell.

Library of Congress Cataloging-in-Publication Data

Baldwin, Andrew, 1950–
A handbook for construction planning and scheduling / Andrew Baldwin, David Bordoli.
pages cm
Includes bibliographical references and index.
ISBN 978-0-470-67032-3 (paperback)
1. Building–Superintendence. 2. Production scheduling. I. Bordoli, David. II. Title.
TH438.4.B35 2014
624.068′4–dc23

2013043938

A catalogue record for this book is available from the British Library.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Cover image courtesy of Shutterstock
Cover design by Andrew Magee Design Ltd

Set in 10/12pt Sabon by SPi Publisher Services, Pondicherry, India

1 2014

Contents

Notes on Contributors

Simon Austin BSc, PhD, CEng, MICE
Simon Austin is Professor of Structural Engineering in the School of Civil and Building Engineering at Loughborough University. Prior to this, he worked for Scott Wilson Kirkpatrick & Partners and Tarmac Construction. He has undertaken industry-focused research for over 30 years into the design process, integrated working, value management, structural materials and their design. The latter includes the behaviour and design of structural elements, sprayed, cast and, most recently, 3D printed concretes. Most of this research has been funded by the EPSRC with collaboration from industry and the findings disseminated in over 200 publications. A strong believer in extending academic research into practice, Simon has served on various BSi and CEN standardisation committees and is a consultant member of two trade associations. In 2001, he co-founded Adept Management, a management consultancy specialising in design, development and engineering management. The company works with many large construction clients, designers and contractors, particularly helping in planning and process improvement.

Andrew Baldwin PhD, MSc, BSc (Hons), FICE, Eur Ing
Andrew Baldwin is an Emeritus Professor of Loughborough University where he was previously Professor of Construction Management in the School of Civil and Building Engineering. His background is Civil Engineering, and he worked extensively in the UK construction industry on major capital projects before embarking on an academic career. These capital projects included major roadworks, offshore engineering projects and major flood defence systems where he gained extensive planning and scheduling experience. His research interests have focused on construction planning, information modelling, process improvement and the development of new ways of working for both design and construction. He has worked in the United Kingdom, Hong Kong and mainland China. His last research management position at Loughborough University was as Director of the Innovative Manufacturing and Construction Research Centre (IMCRC), a major research centre which comprised some 50 academic staff engaged on a

range of innovative research projects. He is currently a Co-Director of the National Centre for International Research of Low-Carbon and Green Buildings at Chongqing University, China.

David Bordoli BSc, MSc, FCIOB, MAPM, ACIArb
David Bordoli is an extremely experienced planning professional who began his career as a planning engineer with construction contractors following graduating in Construction Engineering in 1978. His first appointment as an expert witness was in 1989, where he used innovative network techniques to analyse project delays. In 1994 he returned to academic studies where he first met Professor Andrew Baldwin with whom he subsequently authored a number of articles and papers including 'A methodology for assessing construction project delays' which developed the analysis technique now known as 'Time Impact Analysis'.

In 2001 David left general contracting to work as a consultant, providing contractual advice, preparing time delay claims, reports for adjudications, arbitrations and litigation, and undertaking expert witness appointments in delay and disruption disputes in construction and engineering. In 2012 he was appointed a Director of Driver Consult and has recently spent most of his time working on overseas projects, particularly in South Africa.

Sam Ewuosho BSc (Hons)
Sam Ewuosho inherited an interest in engineering from his father who gained a BEng in Mechanical Engineering. However, a brief period with a local architectural firm at age 16 led him to undertake an undergraduate programme in Construction Management at the School of Civil and Building Engineering at Loughborough University. This programme included construction site experience with a leading UK construction organisation and a period of study in Hong Kong where he studied international real estate and was part of research task force that sought ways to transform a valuable but disused coastal stretch of the Hong Kong Special Authority region. He graduated from Loughborough in 2012 with a First Class Honours degree and is currently undergoing professional development with an international financial services and consulting organisation.

Alistair Gibb PhD, BSc, CEng, MICE, MCIOB
Alistair Gibb is the European Construction Institute (ECI) Royal Academy of Engineering Chair of Complex Project Management. He leads the ECI, a pan-European, evidence-based organisation, providing pragmatic, industry-focused evidence through research collaboration between industry and academia. The ECI, based at Loughborough, provides a knowledge network, with processes and programmes for disseminating, assessing and managing knowledge. Alistair joined Loughborough University in 1993, following a career in engineering and project management with John Laing, Taylor Woodrow and Sir Robert McAlpine. He leads Loughborough's Construction Health and Safety Research Unit, working closely with the Health and Safety Executive (HSE) and industrialists, maintaining a leading role in UK, European and international networks in health and safety.

Sarah-Jane Holmes BSc (Hons)
Since graduating from Loughborough University with a degree in Architectural Engineering and Design Management, Sarah-Jane Holmes has undertaken the role as an Environmental Advisor for a major contractor, Keepmoat Ltd. Her current role within the Environmental Team focuses on the implementation of the environmental management system, policies and procedures throughout a range of new-build and refurbishment projects. In particular, this focuses on waste management, more specifically site waste management plans, and broader environmental compliance issues on-site, through the creation and delivery of best practice guidance, environmental training and on-site auditing. Currently, she is working towards chartered membership of the Chartered Institute of Building (CIOB) and full IEMA membership of the Institute of Environmental Management & Assessment IEMA.

Baiyi Li PhD, BSc (Hons)
Baiyi Li graduated from Chongqing Jianzhu University (Chongqing University), China, in 1999. After a period of working in the local construction industry, he decided to secure a postgraduate degree. He completed his PhD at Loughborough University, UK, in 2008 under the supervision of Professor Simon Austin and Professor Tony Thorpe. In this research, a generic preconstruction planning process model with a method to support the management of preconstruction planning was developed and validated. With extensive construction experience, Baiyi Li is recognised as a leading expert in innovative construction planning techniques and their use on large capital projects including commercial centres, airport and new town development.

Mohamed Osmani BA (Hons), Dip Arch, MSc, RIBA, HEA
Mohamed Osmani is a Senior Lecturer in Architecture and Sustainable Construction at Loughborough University. He teaches on undergraduate programmes and postgraduate courses in the areas of architecture, sustainable building design and construction and CAD modelling and rendering. He has more than 10 years industrial experience as an architect and over 15 years as an academic. Mohamed has developed a significant portfolio of research projects and has been a member of numerous committees and task groups including the CIRIA Sustainability Advisory Panel, House of Lords Waste Enquiry, the UK Green Building Council Vision for Sustainable Built Environment, the Office of Government Commerce Construction and Refurbishment: Building a Future and the British Standards Institution (BSI).

Stacy Sinclair BA (Hons), MSc, RIBA, SCL, AS, DRBF, DBF
Stacy Sinclair, a solicitor at Fenwick Elliott LLP, advises on a broad range of construction and engineering issues. Before qualifying as a solicitor, Stacy practised as an architect, principally designing large-scale projects such as stadiums, hospitals and education buildings both in the United Kingdom and the United States. Stacy has a particular interest in Building Information Management (BIM) and its impact on the construction industry and regularly writes for *Building Magazine* and the *RIBA Journal*. She is the co-editor of the *Dictionary of Construction Terms* and is also a lecturer and oral examiner on the RIBA Part III postgraduate course at a number of universities.

Foreword

This is an excellent publication that will be welcomed by both practitioners and students.

Although the subject of planning and scheduling is a 'mature' academic subject and the basics well established, as with all aspects of construction practice, the requirements of the construction client and demands of the industry continually require a re-assessment of current practice.

This publication is timely. It reviews current practice, returning to the basics of the topics and reiterating the fundamentals. It then examines current planning and scheduling methods including the new methods of working that are emerging to meet the demands of both contractors and design managers. It also considers Building Information Management, (BIM) and its impact on planning and scheduling. Other additional topics relate to the need for sustainable construction and planning to meet the requirements of health and safety.

Regrettably the construction industry still regularly fails to meet the targets for the completion of projects on time and at cost. Section IV by David Bordoli is an excellent summary of how delay and disruption may be assessed both from the perspective of assessing the impact of delays and seeking compensation.

Andrew Baldwin and David Bordoli have a wealth of experience that is founded in management thinking and industry based. This means that the text focuses on the requirements of practitioners. The style of the text ensures that the detail required by the reader is easily accessible. The book may therefore be either a supporting text for an academic course or the reference book for the construction planner in industry. In addition to the knowledge of the main authors it includes contributions from a number of colleagues within the School of Civil and Building Engineering at Loughborough University, one of the leading universities in the United Kingdom.

I strongly recommend it to you.

Professor Li Baizhan
Director, National Centre for International Research
of Low-carbon and Green Buildings
Chongqing University, Chongqing
P.R. China

重慶大學
CHONGQING UNIVERSITY

Preface

Why another book about Construction Planning and Scheduling? Planning and scheduling is a 'mature' subject. The knowledge base is long established; there are many excellent texts specifically on the subject. Planning and scheduling is covered in many excellent project management and business management textbooks. Why another book?

Although the basis for construction planning and scheduling is long established and the subject firmly embedded in university and college teaching programmes, there is substantial evidence that most planners and schedulers are trained by experience 'on the job'. Planners and schedulers are, in the main, self-taught. This learning extends over time and like all industry-based learning needs to be supported by the knowledge and experience of others.

The aim of this handbook is therefore to present the key issues of planning and scheduling in a clear, concise and practical way in a readily acceptable format whereby individual chapters and sections can be accessed and read in isolation to provide a guide to good practice. Our objective was to provide a text to accompany learning, a reference document which, supported by web-based information, would provide information on the background to planning and scheduling together with guidance on best practice and practical methods for the application of construction planning and scheduling on different types of construction work. In addition to revisiting the basic elements of planning and scheduling, we have included chapters on current topics that are demanding consideration by all those within the construction industry. These include planning for sustainability, waste, health and safety and Building Information Modelling (BIM).

The book is divided into four sections.

The first section looks at planning and scheduling within the construction context. It provides both an outline of the evolution of planning and scheduling and a review of the basics: who plans, when and why. We consider the overall project cycle and then explore what the construction planner actually does and how the form of procurement adopted by the client impacts both the type of planning undertaken and when planning takes place. We complete the first section by looking at different construction management schools of thought and how these approaches influence how the managers of construction organisations plan, monitor and control construction projects.

The second section looks at planning and scheduling techniques and practice. There are numerous planning and scheduling techniques available to assist the construction planner. These have been developed over extended periods of time. We provide details of the basis of these techniques and then look at how they are used in practice and how they are adopted, adapted and utilised in practical situations. This section also looks at other aspects of planning such as how the cash flow for the contract may be calculated, the method statements that need to be produced and the uncertainty and the risks that may arise due to insufficient information.

The third section considers planning and scheduling methods and how the techniques described and discussed in Section II are incorporated into current ways of working including Critical Chain Project Management, Earned Value Analysis, Last Planner, ADePT (for planning the design process), BIM, Planning for Sustainability, Planning for Waste Management and Planning for Health Safety and the Environment.

Delays and disruption are an inevitable part of most construction projects. The fourth section, Delay and Forensic Analysis, looks at delay and disruption, their differences and how their impact on the original production schedule may be assessed. We look at the different approaches used and the information required in order that the analysis may be undertaken. Practitioners who specialise in this 'forensic analysis' have established protocols on how to approach their modelling and analysis. We look at the approach adopted by the Society of Construction Law Delay and Disruption Protocol and the Recommended Practice for Forensic Schedule Analysis produced by the Association for the Advancement of Cost Engineering International (AACEI). We outline both these protocols, their background and their guidance on method implementation, analysis evaluation and method analysis selection.

Analysing delays and disruption is seldom straightforward; a number of other issues may need to be taken into consideration. We look at issues including out-of-sequence progress; the effect of different types of calendars; the impact of abnormal weather; concurrent delays; the relatively new concept of pacing, mitigation, acceleration and the impact of different employer, contractor and subcontractor schedules. We define each of these and provide guidance on how to go about assessing the implications of each of these on the planner's analysis on the construction schedule.

Together, each of these sections provides a basis for the understanding of both the basics of planning and scheduling techniques and how they may be used in practice. We define planning and scheduling and differentiate between these two terms. Our research for the book identified that whilst there is no confusion over the meaning of 'planning', there is frequently discussion with respect to the terms 'scheduling' and 'programming'. Throughout the text, we have adopted the term 'schedule' in preference to 'programme'. In the United Kingdom and current and former Commonwealth countries, 'programme' was generally the preferred term. However, increasingly the original American term 'schedule' is being adopted throughout the world. We also note that in the United Kingdom, the term 'schedule' may also refer to a tabular list of information. For example, an 'information required schedule' is a tabular list of information items and dates by which the information is required by the project team. Terminology is always important.

To assist the practitioner, there is an extended glossary of terms in which the terminology used by practitioners is explained.

In writing the book, we have considered not only our own knowledge gleaned from industry experience and academic study but also the experience of many other industry practitioners and leading academics. We have reviewed conference and journal papers and considered recent research findings. It was never our intention to 're-write the subject' but rather to provide a handbook that included links to the important works of others. Here, we have revisited standard texts such as those of Frank Harris and Ron McCaffer and recognised highly rated works such as those by Michael Mawdesley, William Askew and Michael O'Reilly, Thomas Uher and Adam Zantis, and Brian Cooke and Peter Williams. We have also incorporated information from the current guides and best practice produced by professional institutions. These include several publications by the Chartered Institue of Building CIOB: the CIOB Guide to Estimating; the CIOB Guide to Good Practice in the Management of Time in Complex Projects; and the CIOB Code of Practice for Project Management for Construction and Development; all of which we believe the practitioner should always keep readily available for reference and guidance.

Acknowledgements

The handbook could not have been produced without the help and assistance of others. We should like to thank all those who have assisted in the preparation of material and the production of the book. First are the contributors who have provided contributions in the form of individual chapters: Simon Austin, Alistair Gibb, Baiyi Li, Mohamed Osmani, Sam Ewuosho, Sarah-Jane Holmes and Stacy Sinclair. Some are long-standing friends at Loughborough University, others are more recent colleagues. We are delighted that Stacy Sinclair of Fenwick Elliott LLP was willing to assist us with consideration of the legal issues relating to BIM and how this new way of working impacts the industry. For this important perspective we are extremely grateful.

Lean Construction is a way of working that is now firmly established in the construction industry. We should like to thank Glenn Ballard and Ian Mossmann for their assistance in providing background material for us to use within the text and also their time in reviewing drafts of the text. Their contribution has been invaluable to our understanding of not only how Lean Construction thinking has evolved but also the current perspectives.

More difficult to identify by name but no less valuable are the academic colleagues and industry practitioners who over the years have extended our knowledge and improved our thinking around the subject of planning and scheduling for construction. They too have all contributed to this text, even though they may not have been aware of their potential contribution when we discussed issues and problems in the context of the projects on which we were working. We nevertheless thank them for their time and perspectives on the problems under consideration. We should also like to thank Driver Trett, Loughborough University and the 'One Thousand Experts' programme for their support for the production of the book. Finally, we should like to thank Andy Mathers and Christine O'Mahony for their artwork and Madeleine Metcalfe and all the editorial and production team at Wiley-Blackwell for their time, patience and understanding.

Andrew Baldwin and David Bordoli
January 2014

About the Companion Website

This book's companion website is at

www.wiley.com/go/baldwin/constructionplansched

where you will find freely downloadable support materials.

Section I
Planning and Scheduling within the Construction Context

Introduction

This section comprises two chapters. Chapter 1 looks at why and when we plan. It considers different types of planning within the context of a construction project. It looks at the differences between Planning, Programming and Scheduling and the costs and benefits of undertaking these tasks on a project. We look at the planning process with the construction project cycle within the context of several different frameworks. Production in all industries requires planning. What are the distinct characteristics of planning in the construction industry? We look at how the clients of construction work procure the new assets and services that they require, what is unique to construction, what is similar to other industries, what has happened in the past and what may happen in the future. It is widely accepted that there are four functions of management – Planning, Organising, Control and Leadership – and that good planning is imperative for successful management. Chapter 2 looks at how planning is considered by the leading construction management schools of thought. We examine the position of planning in each of these perspectives and at the 'root theory' of each school, their current thinking, how they compare when considering the demands of complex construction projects and their perspective on the role of planning in the project process.

A Handbook for Construction Planning and Scheduling, First Edition. Andrew Baldwin and David Bordoli.

Chapter 1
An Introduction to Planning and Scheduling

A brief history of planning and scheduling

Frederick Winslow Taylor was the founder of modern scientific management. His studies in the latter part of the 19th century formed the basis for management thinking in the 20th century and continue through to the present. Currie (1977) states that Taylor's work and philosophy may be seen in three major phases. First, he made improvements in the management of production. These sprang from his application of scientific methods. Second, he introduced systems of pay designed to produce 'a fair day's work for a fair day's pay'. Then, moving from the individual scale to the overall scale, he produced his 'grand design' for an industrial society. He hoped that this 'grand design' would lead to improved standards of living. His detailed, careful analysis of production tasks and functions led to new machines and tools, new methods of production control and stock control and new office procedures. Taylor's contribution to manufacturing production scheduling was establishing the planning office in a separate location away from the production area and the recognition that planning was a decision making process that required sharing of information. This and his other works attracted the attention of many other industrialists and professionals.

Henry L. Gantt (1861–1919) was a teacher, draughtsman, engineer and management consultant. He was contemporary and protégé of Taylor, and between 1887 and 1893 he worked with him in his experiments at the Midvale Steel Works (Currie, 1977). His contribution to manufacturing production management includes the application of scientific analysis to all aspects of production, the introduction of tasks and bonus systems where the bonus was linked to how well managers taught employees to improve performance and the social responsibility of business. Gantt focused on the motivation of workers and the application of knowledge to the advantage of all concerned with a

A Handbook for Construction Planning and Scheduling, First Edition. Andrew Baldwin and David Bordoli.

business. He believed that business organisations had an obligation to the welfare of the society in which they operate and this directed much of his thinking. He developed the Gantt chart, a chart that allowed supervisors to identify and schedule the work of each worker and then review and assess the actual production. Gantt did *not* invent the bar chart, the concept of bar charts pre-date Gantt's work by at least a century. Gantt took existing methods of visually displaying work tasks and developed them to produce a new chart to form a visual statement of productivity. He also recognised the advantages of reducing inventory and clean, well laid out workspace and developed other management techniques (Weaver, 2012).

Critical path methods

For the first half of the twentieth century the bar chart was the dominant technique for planning and scheduling on projects of all sizes. This changed in the 1950s. A bar chart is excellent at showing *when* activities are scheduled to take place. However, it fails to show the *inter-relationships* between activities and the effect of delay in individual activities on the overall project. The decade of the 1950s included many major military, industrial and infrastructure projects both in the United Kingdom and the United States, and new systems were sought to manage these complex projects. Within the operational research community there was widespread interest in solving the problem of modelling the inter-relationship between the activities within a project.

By 1957 the Central Electricity Generating Board (CEGB) in the United Kingdom had developed a technique for 'identifying the longest irreducible sequence of events'. At the same time work in the United States, the U.S. Navy Special Projects Office was devising a means of planning and controlling complex projects. July 1958 saw the publication of a report entitled PERT, Summary Report, Phase 1 in which the technique entitled the 'Programme Evaluation Review Technique' (PERT) was proposed. In October 1958 it was decided to apply PERT to the Fleet Ballistic Missiles Programme. Meanwhile at the U.S. company E.I. du Pont de Nemours a technique called the Critical Path Method was under development. (For more details see Lockyer, 1974.)

Early successes of these techniques led to their widespread adoption by project managers, and the next decade saw the development of the techniques by researchers in academia and industry and their use across a range of projects. Originally the calculations were undertaken manually, then using computer programs operating on large mainframe computers. The generic term 'Critical Path Analysis' (CPA) arose emphasising the ability of the technique to identify the key activities that form the shortest duration for the project.

Two forms of the technique emerged: activity-on-arrow and the precedence method. By the early 1970s CPA was the *de facto* standard for planning and scheduling major projects and was adopted by both clients and contractors for project planning, monitoring and control. However, project managers soon discovered that adopting the technique did not guarantee the success of the project. For some projects the technique simply highlighted the problems. On others the technique (or rather its use) became the problem.

A report by NEDO compared construction performance on major engineering projects in the United Kingdom, Europe and the United States. It found 'That there was no correlation across the case studies between the sophistication with which programming was done and the end result in terms of successful completion on time'.

It became clear that CPA-based planning and scheduling systems were only an aid, albeit an important one, to the project manager and not a panacea for poor management. 'There was a general feeling that project planning was generally unsuccessful, that project planning using network planning was even more unsuccessful and that network planning using computers was the least successful of [all] techniques' (NEDO Report, 1983). Enthusiasm for the technique waned. Many project managers who were required contractually or by their organisations to use the technique paid only lip service to it.

Its use was resurrected by the introduction of the micro-computer, now generally known as the PC.

The impact of the PC

The introduction of the personal computer/micro computer provided cheap 'local' computing power for every office and every construction site. This meant that the time required for the preparation of plans and the production of bar chart schedules could be significantly reduced and they could become readily available to the construction team. 'The bar chart was no longer out of date before you pinned it to the wall' (Reiss, 1995).

The success of the IBM PC (introduced in 1981), its subsequent models and alternative computer products resulted in the production of many new software applications including new software for CPA. Soon, CPA software was re-packaged and marketed to all industries as a 'Project Management System'. New features were added. Some of these products adopted a new approach to inputting and displaying project data that was based on a bar chart format. This combined with improved facilities for producing and printing the output of schedules led to the 'linked bar chart' software product. This linked bar chart format became the preferred form of planning and scheduling for many planning engineers and led to a resurgence in the use of project management software.

With the opportunities of new computer systems came an awareness that the successful adoption of computer systems requires more than just hardware and software but consideration of data, procedures and people. There came a wider appreciation of the need to plan the implementation of systems around the users, not the computer hardware and related equipment. Moreover, there was a clear need to develop and work with collaborative systems whereby all parties involved in the project may contribute to the project planning scheduling and monitoring process. The boundaries between the technical innovations of information and communication technologies and the human aspects of systems adoption and performance became less distinctive. However, the success of project management systems in the overall management of construction projects remained inconsistent. This led to new systems and new thinking.

New systems and new thinking

The decade commencing 1990 saw the development of two important developments in planning and scheduling: Critical Chain Project Management (CCPM) and Last Planner. Both were the result of the realisation that, even with the cheap computing power and many additional features, the adoption of existing project management systems could not ensure project success.

CCPM focuses on the uncertainty in schedule activities and identifies the key activities that, based on time and resource constraints, form the 'critical chain' for the construction work. Rather than adopt traditional critical path methods that allow individual managers to create and use up buffer time relating to 'their' activities, CCPM creates a 'project buffer' and argues that production should monitor this buffer time on an on-going basis, always allocating resources to critical chain tasks. CCPM stresses the importance of focusing on the critical activities and the resources required to complete these activities. It argues that by monitoring the project buffer time you will ensure successful project completion. Advocates of CCPM claim that the introduction of the CCPM methodology ensures project success, reduces project durations, enables increased project throughput with no resource increases, and reduces manager and worker stress, all with minimal investment.

Last Planner was developed from research that concluded that even with the strict adoption of critical path planning techniques only 50% of the activities on a typical construction project were completed to schedule. One major shortcoming of CPM is that it is ill suited to direct production on site. Ballard and Howell (1992) argued that the CPM approach as a basis for production planning was fundamentally flawed and that production should only commence if all the resources required for the completion of an activity are available, that is, you should consider not only what *should* be done but what *can* be done. Introduced in 1992 the Last Planner System has become the platform for Lean Construction and is now fully recognised as a proven approach to production-based construction management.

New information and communication technologies

The last decade has seen the emergence and acceptance of Building Information Modelling (BIM) and Virtual Prototyping as the basis for the design, production and maintenance of many new buildings. These technologies together with a focus on sustainable building developments and new procurement requirements are influencing the thinking of both public and private clients who are demanding new standards and new ways of working.

The ability to model the building product and link the contents of the building model to other systems was first developed in the 1980s. With respect to construction planning this became known as 4D Planning and typically comprised the ability to link the elements and quantities from the computer model to project management software to introduce the dimension of time and generate simulations showing how the construction would proceed throughout the duration of the project. (Similarly, using product model data to analyse cost has become known as 5D planning.)

The use of digital product models for all aspects of building design and management is now known as building information modelling or BIM. The development