Whole Life-cycle Costing
Risk and Risk Responses

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Foreword by Nigel Dorman, NHS Estates

The UK government has challenged the way its organisations deliver services, and has placed on them a duty to continuously improve in order to provide the services that people require economically, efficiently and effectively. This concept of 'best value' has dominated public sector capital investment policy in the UK since the 1990s. This has been the case particularly in large buildings and civil infrastructure projects such as hospitals, prisons and highways. As a result of the fundamental revisions in public procurement policy that have subsequently taken place, interest in and demand for the use of whole life-cycle costing (WLCC) techniques have risen to unprecedented levels. These policy changes are clearly demonstrated in recent government publications such as '*Construction Procurement Guidance, No 7 Whole Life Costs*' (Office of Government Commerce), which states that 'all procurement must be made solely on the basis of value for money in terms of the optimum combination of whole life costs and quality to meet the user's requirements'. This view is fully endorsed by National Audit Office (NAO) policy and reinforced in their joint guide '*Getting value for money from procurement – How auditors can help*'. Consequently the award of public construction contracts based on simply the lowest capital cost bid is no longer recognised as good practice; best value must be taken into account and thereby WLCC should be fully appraised as part of the decision making process.

Within the UK public sector, WLCC must now be taken into account in all business cases, which aim to justify capital investment in construction. This applies to projects financed by traditional public capital as well as through the Private Finance Initiative (PFI) and Public–Private Partnership (PPP) approaches. The tangible effects of this essential change in procurement can be seen in, for example, the NHS ProCure 21 strategy. ProCure 21 promotes the better use of NHS assets and resources to achieve the right buildings and equipment, in the right place, in the right condition, of the right type, at the right cost (from both capital and whole life points of view), at the right time whilst facilitating effective response to future needs of the service with minimal impact on the environment. The ProCure 21 programme incorporates WLCC models in the tendering process for its frameworks and requires specific models to be completed for each NHS scheme subsequently undertaken by the framework contractors in England. These models have helped the NHS to make significant steps forward in attaining better value for money in capital procurement.

The transition to WLCC-based decision making has been slow and arduous, as this book will demonstrate. The techniques of WLCC have been viewed by many as a complex and highly uncertain science, two descriptions that are perhaps not wholly without merit. In respect of the latter, this book studies in depth the element of 'risk' in WLCC, and presents possible strategies and techniques for dealing with this. However, the continuing research into WLCC will provide us with better models with which to inform the decision making process and deliver best value to NHS stakeholders in the future. This book bears evidence to this, providing examples of the practical applications of the technique and the subsequent benefits that can be obtained.

The authors are to be congratulated on this timely and thought-provoking work, which shows the real value of WLCC, particularly within the economic constraints surrounding public procurement today. I feel sure the book will provide an indispensable reference to practitioners as well as a useful study guide to undergraduate and postgraduate students in the construction and economic disciplines.

Mr Nigel Dorman, BSc, CDipAF, FRICS, FIHEEM
Head of Construction Performance
National Health Service Estates
The United Kingdom Department of Health

Further reading

National Audit Office/OGC. *Getting value for money from procurement – how auditors can help*.
Office of Government Commerce OGC. *Construction Procurement Guidance No 7 Whole Life Costs*.

Useful websites

www.nhs-procure21.gov.uk
www.nao.gov.uk/guidance/topic.htm
www.ogc.gov.uk

Preface

The construction industry has recently experienced a paradigmatic shift in its approach to product delivery and the achievement of customer satisfaction. Where previously the design and construction teams placed a heavy emphasis on delivering buildings at the lowest capital cost, a greater awareness and desire to consider costs over the whole life of the building have prevailed. Clients now want buildings that demonstrate value for money over the long term, and are not interested simply in the design solution which is the least expensive. These changes have led to and highlighted the importance of whole life-cycle costing (WLCC) approaches to the design, construction and operation of buildings.

Rethinking Construction, the government report into the industry, strongly advocated the need to build right first time and every time by considering the long-term costs and economic performance of constructed assets. Additionally, recent health and safety legislation has also placed a specific duty on clients and designers to consider the potential risks of construction, maintenance and operation over the whole life of the building. These drivers, along with the increase in the number of buildings procured under the Private Finance Initiative (PFI) and Public–Private Partnerships (PPP) routes, have led to project stakeholders taking a greater interest in WLCC decision making. So why is WLCC so important?

One of the reasons behind the rise in popularity of WLCC is that it provides a far more accurate assessment of the long-term cost effectiveness of a project than standard economic methods that focus solely on first costs or on operating-related costs in the very short term. WLCC provides vital information on projects such as those procured under PFI, where the consortium requires long-term cost forecasts of service provision that they will be contracted to provide. It also provides the government with knowledge about the anticipated economic liabilities that they will acquire when the asset becomes the property of state. This, however, is just one example of the benefits of WLCC.

Standard cost and value analysis techniques are generally used to quantify and assess the economic implications of a building design. While these techniques do provide a basis for making project cost decisions, they often do not account for many of the parameters, which may affect the actual project value or cost. The existing methods also fail to consider formal decision making processes and risk assessment methods in performing a cost benefit analysis. Investments in buildings are long-lived and as a consequence involve some degree of uncertainty over the life of the building, and the operational and maintenance costs, amongst other factors. If there is substantial uncertainty concerning cost and time information, then a WLCC analysis may have little value for decision making if it fails to account for this. Therefore, it is essential to assess the degree of uncertainty associated with the WLCC results and to take this additional information into account when making decisions.

The book is structured in three parts, each reflecting the importance of WLCC throughout the various stages of the whole life of a building or constructed asset. Although the examples in this book are taken from the construction industry, the intentional aim of this book is to be as generic as possible, demonstrating WLCC with risk assessment as universally applicable to many other capital investment decision making scenarios. The book presents a logical approach to the understanding, development and execution of a WLCC analysis, with the express intention of promoting and inspiring confidence in the process.

Part I deals with fundamentals of WLCC and consists of five chapters, which provide a general background and appreciation of WLCC concepts, whole life risk management techniques and key decision making milestones through the project life. Throughout this book, the terms 'building asset, building facility and project' are used interchangeably and are taken in their widest possible meaning, to incorporate all aspects of the development from inception to eventual decommissioning.

Part II covers aspects relating to WLCC risks and risk responses during the design stage, and consists of five chapters. A key theme in this Part is the concept of integrating service life forecasting, environmental life-cycle assessment and WLCC. Additionally, it also introduces a practical framework for assessing whole life risks and risk responses during the design stage. Part II also includes an innovative framework for developing WLCC budget estimates. The Part concludes with a case study on the practical application of WLCC to the selection of mechanical services. This Part is written in a way that should provide stimulus to the reader to think about WLCC and risk during the design stage, and encourage a holistic approach to design decision making.

Part III considers WLCC issues during the post-design stage of the building life. This includes the analysis of WLCC risks and risk responses during the construction and operational phases. Example risk registers are presented here with guidance on how the analyst should approach and deal with risk. We will also look at some innovative approaches to operational stage WLCC analysis, both for new projects and existing buildings. This Part concludes with a case study example of the application of WLCC in asset occupancy analysis.

Throughout, the book contains a mixture of established theory, practice and innovation relating to WLCC budgeting and risk management. Although we cannot expect to cover all aspects of WLCC, guidance on suitable sources of additional information is provided. Readers who wish to explore some of the issues in the book in greater detail should refer to the list of further reading and references at the end of each chapter.

Halim Boussabaine
Richard Kirkham
Liverpool
May 2003

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Finally, we would like to thank our families for their support and encouragement, who no doubt found the ordeal of helping us through the long nights as equally stressful as we did.

The authors affirm that any mistakes and errors in the book are entirely our responsibility.

> *Ideals are like stars. We never reach them but, like the mariners on the sea, we chart our course by them.*
>
> Carl Schurz

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Part I
Fundamentals of Whole Life-cycle Costing

Chapter 1: Towards an Understanding of Whole Life-cycle Costing

Chapter 2: Whole Life-cycle Costing Risk Management

Chapter 3: Key Decisions in the Whole Life-cycle Costing Process

Chapter 4: Fundamentals of Whole Life-cycle Cost Analysis

Chapter 5: Whole Life Risk Analysis Techniques

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1 Towards an Understanding of Whole Life-cycle Costing

1.1 Introduction

Value for money is a concept that is frequently considered when an individual or an organisation is seeking to make a purchase or investment. When acquiring a new car, for example, we may consider the costs of ownership (fuel economy, insurance, maintenance, availability of replacement parts, etc.) when deciding between options. Implicitly then, we consider the long-term costs of ownership in the decision making process. Furthermore, it could be argued that the larger the capital cost of a product, the more important it is to consider these long-term costs. Buildings are a prime example of high cost purchases, yet consideration of long-term costs is not given the attention it deserves. The past 30 years have seen many attempts to encourage a holistic approach to what is in effect 'whole life' cost analysis, but with limited success, particularly in the United Kingdom. One such technique that is currently emerging in the industry is whole life-cycle costing (WLCC).

Whole life-cycle costing is a relatively new concept to the construction industry, albeit based upon the foundations of analytical techniques that have been in existence for some time. It is in essence an evolution of life-cycle costing (LCC) techniques that are now commonly used in many areas of procurement. Like LCC, the primary purpose of WLCC is to aid capital investment decision making by providing forecasts of the long-term costs of construction and ownership of a building or structure. However, unlike LCC it is also a dynamic approach, and can provide up-to-date forecasts on cost and performance throughout the life of the building. Some of the ideas behind the justification for WLCC are synonymous with key issues in today's construction industry:

- *Meeting clients' expectations* Clients (especially in the public sector) now require buildings that are efficient during and after construction. WLCC techniques can demonstrate real cost savings in design solutions
- *Sustainability* Achieving sustainable design solutions relies on the consideration of long-term operational costs and performance of building components
- *Monitoring performance of constructed assets* For example, are PFI/PPP (Private Finance Initiative/Public–Private Partnerships) projects really

cost effective? Only by considering the whole life-cycle costs can this be assessed. Using WLCC also supports benchmarking and key performance indicators

- *Monitoring cost effectiveness of constructed assets* WLCC provides the means by which to constantly review this and base future capital investment on this information
- *Lean construction* By considering long-term cost and physical performance, waste is minimised both during construction and through the life of the building.

The aim of this chapter therefore is to provide a general overview of the fundamental ideas and principles behind WLCC and to demonstrate how it can be of benefit to the construction industry practitioner. The chapter initially examines the history of LCC and its various definitions, moving on to show how WLCC has evolved from LCC as a new and innovative cost analysis tool. The failings of previous LCC methodologies are examined by definition of the innovative aspects of WLCC.

1.2 Whole life-cycle costing: a brief history

Prior to the 1970s, most clients, developers and professionals involved in building procurement made capital investment decisions solely on the basis of capital cost. Outside the construction industry, it was appreciated in some quarters that making decisions solely on capital cost could be folly. They believed that by possibly spending more in capital cost, the long term would realise substantial cost savings when compared with a cheaper alternative. This school of thought was known as 'terotechnology', and it was in effect the beginnings of whole life-cycle cost theory. Within the construction industry, nevertheless, terotechnology was largely ignored. Some of the reasons behind this included an ignorance of the importance of whole life-cycle costs, lack of available data and data collection mechanisms, and the fact that those providing the capital generally had no interest in the subsequent operational costs of the building. In the early 1970s, the term 'cost-in-use' began to

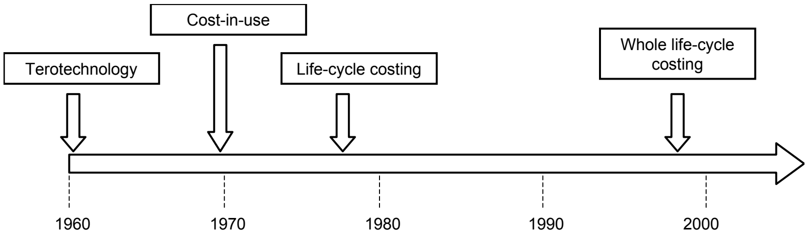

Fig. 1.1 The evolution timeline of whole life-cycle costing.

appear in the industry and the literature. Cost-in-use refers to the expenditure related to the operation of an asset. Although not related specifically to the construction industry, it was recognised that the underlying principles of cost-in-use could apply to buildings and critical structures. What cost-in-use failed to consider, though, was the necessity for accurate future cost forecasting. It became clear then that some kind of technique was required to facilitate this.

It was not until the mid to late 1970s that LCC emerged as a solution to this problem. LCC fostered a wide-ranging approach to cost appraisal, encompassing all perceivable costs from construction through to eventual disposal – 'the whole life'. Using a variety of forecasting techniques, the analyst was able to demonstrate how increased capital cost could be offset by long-term cost savings. LCC sounded good in theory, but the practical implementation within the construction industry did not reflect this. In terms of the enlargement of life-cycle costing theory, the major factor which frustrated its development was lack of good quality cost-in-use and performance data. This proved to be the principal dissatisfaction felt by those who showed some willingness to employ life-cycle costing techniques.

In 1971, the Royal Institution of Chartered Surveyors established the Building Maintenance Cost Information Service (BMCIS) as a method of collecting operational and running cost data. Its main aim was to adopt a single classification system, which could then be disseminated among subscribers in a common demeanour. Although the BMCIS went some way to addressing the implementation problems of life-cycle costing, it did not address the need for a coherent framework and structure in which to deal most effectively with this information.

In 1977, the then UK Department of Industry published *Life-cycle costing in the management of assets* which presented one of the earliest definitions of LCC:

> 'A concept which brings together a number of techniques – engineering, accounting, mathematical and statistical – to take account of all significant net expenditures arising during the ownership of an asset. Life-cycle costing is concerned with quantifying options to ascertain the optimum choice of asset configuration. It enables the total life-cycle cost and the trade-off between cost elements, during the asset life phases to be studied and for their optimum selection use and replacement.'

Since 1977, LCC has become widely reported on, with a diversity of models and techniques existing. In 1983, two eminent researchers in LCC, Roger Flanagan and George Norman, developed a framework for collecting data, which could then be used to build up the life-cycle cost of a project. By 1992, LCC was a familiar concept to building economists throughout the world, and as such became a recognised standard in the UK under British Standard BS 3843 (1992):

> 'The costs associated with acquiring, using, caring for and disposing of physical assets, including feasibility studies, research and development, design, production, maintenance, replacement and disposal; as well as all

the support, training and operations costs generated by the acquisition, use, maintenance, and replacement of permanent physical assets.'

In 2000, this definition was revised and incorporated into ISO 156868 Part 1 – Service Life Planning which cites LCC as (ISO 2000):

> 'A technique which enables comparative cost assessments to be made over a specified period of time, taking into account all relevant economic factors both in terms of initial capital costs and future operational costs.'

The BS/ISO definition, although authoritative, is a daunting and perhaps vague definition given the plethora of cost items that could be included within each cost category. Principally, the authors believe this to be one of the reasons why LCC is still rarely used to the extent that it was initiated for, although others argue that the lack of quality data is the principal reason. Additionally, the plethora of cost models and definitions associated with LCC has been significant in creating an 'air of confusion' over the subject. Ambiguity and inconsistency were identified in Newton (1991), where consideration of the problem of model classification and the inability to compare models on a like-for-like basis are discussed. Furthermore, the individual perception of the life-cycle model raises many concerns. This is validated in Smith (1999), which highlights how LCC has for some time become an important issue in the overall cost picture, but has not featured in the decision making process to the same extent. This lends weight to the argument in Kirkham *et al.* (1999) that in some respects LCC has remained an academic rather than a practical tool, and that presently the financial burden of implementing an LCC approach outweighs the advocated benefits.

By way of example, consider the application of LCC in other sectors. It has been widely used in the procurement of United States and Australian defence contracts for some time now (Australian National Audit Office 1998; US Department of Defense 1997, 2001). The sheer cost involved in these kinds of projects emphasises the need for LCC; that is, the possibility that significant capital outlay needs to be justified by the longer-term benefits. In some respects, research has shown that LCC has only been applied to projects that have a very high capital cost. In a significant amount of cases, it has been found that ignoring the likely future costs in the conception stage can lead to a significantly more costly endeavour in the future (Smith 1999).

Towards the late 1990s, the concepts of 'whole life costing' (WLC) and 'whole life-cycle costing' (WLCC) emerged. The terms whole life costing and whole life-cycle costing are interchangeable. WLCC is a new term that appears to have been adopted by many building economists involved in the preparation of forecasts for the long-term cost assessments of capital projects. There has been debate amongst academics and practitioners as to whether a difference really does exist between WLCC and LCC. The key emphasis in most of the definitions lies in the implication that LCC is only concerned with the economic life of the building, in other words the period of commercial interest. It could be argued that WLCC forms the attempt by academia and practitioners to overcome some of the problems of LCC. Moreover, it takes into account the costs of running and operating a building over its entire life span – 'the whole life' – as opposed to over a specified period of time, which is a feature of LCC models. Notwithstanding, some have argued that WLCC is simply synonymous with LCC. Others have specified that a difference exists (Bourke & Davis 1999). In this book, the contention is that the concepts are indeed different and to justify this assumption an online survey was conducted (Boussabaine & Kirkham 2000). The authors sought to assess the opinions of academics and practitioners involved in LCC/WLCC, and to establish if the majority of individuals thought that there was real difference between the concepts. This survey forms part of the backbone of the definition of whole life-cycle costing taken in this book.

1.3 Defining whole life-cycle costing

The online survey revealed a broad spectrum of opinion about the difference (if any) between WLCC and LCC. The following are random examples of the responses:

> 'The term...is whole life costing (WLC) and if you believe the old life-cycle costing (LCC) also included all capital and revenue costs for the whole business case/project and not merely elements, e.g. cladding, ceilings etc. then LCC and WLC are...the same thing.'

> 'By rights they should mean the same thing, with the "whole" being superfluous. When one considers a "life-cycle", its wholeness is implied. However, it [may be] possible that when some refer to LCC, they may be referring to the consideration of only costs incurred up to the point when the asset is no longer economically viable and ignoring the issues that relate to asset disposal – which is considered to be part of WLCC.'

> 'If LCC is anything like life-cycle assessment, its completeness is a continuum...In practice, LCAs suffer dramatically from incompleteness, because environmental impacts have to be traced many transactions upstream. This is not a problem for LCC...I can't imagine what the problem would be regarding a small amount of information about the scope of LCC. Australian and New Zealand standards I have seen on LCC do not define WLCC. [Why] would the additional term be required?'

> 'I believe that WLC is simply the modern [equivalent] of LCC. Cost-in-use remains something different. There may be a shift in emphasis to suggest that WLC is not a one-off calculation, but may also be reviewed during the life of the building.'

> '...As I understand it, WLCC goes slightly beyond that to include costs beyond working life – in the case of a building project therefore demolition costs for example would be included...'

> 'In practice, we refer to WLC as the total operating costs of the building, including energy/utilities costs and facilities management elements that relate to the building, such as maintenance and cleaning. LCC refers to replacement building components within the building such as windows, fan coil units, etc. Over and above this are facilities management costs, such as security and catering.'

> '...Theoretically speaking, there is no difference between LCC and WLCC. Each sector adopts a different term. For example, the manufacturing and military [sectors] use LCC, whilst the construction industry may use WLCC and...oil, gas and prime contracting [companies] use through life cost (TLC). However, in the concept of the Private Finance Initiative (PFI), LCC means life-cycle replacement cost which is a part of WLC.'

It would be fair to speculate, after consideration of the points above, whether we really know what WLCC represents. In the absence of any internationally recognised standard on WLCC, it remains a subjective opinion based upon experience, field of work/study and economic standpoint. Of greatest importance is that not one of the respondents in the survey defined WLCC in similar terms; some though pointed out that LCC and WLCC were two of the same thing. In the absence of any national/international standard, who is to say that the above views are at worst incorrect or at least misguided? Although several institutions within the UK are currently working on WLCC-related projects, how can a wider understanding amongst practitioners and academics be initiated, when the research community as a whole is still confused about terms? Naturally it follows that an urgent need exists to define WLCC.

It is the authors' belief that a tangible difference exists between WLCC and LCC. We see WLCC as an evolution of LCC and not a re-invention of the wheel in terms of its association to LCC. Many have rightly noted that a fundamental problem with LCC is the aspect of uncertainty, the risk that is inherent in future forecasting. Some have gone so far as to say that LCC is based on 'guesswork' and 'speculation'. True, we will never be able to state with a very high degree of certainty how a building will perform economically in terms of operation, maintenance and such like. However, it is possible to quantify that risk, to enable stakeholders and decision makers to base capital investment proposals on a basis by which they are aware of the uncertainty in the forecasts. We are also concerned about the fact that the elemental deterioration of building components and the characteristics of the building itself are not integrated into the WLCC decision making process.

In consideration of the results of the survey, and based upon the previous research activities of the various institutions in the UK and elsewhere, the authors advocate the following definition as that of WLCC:

> 'Whole life-cycle costing (WLCC) is a dynamic and ongoing process which enables the stochastic assessment of the performance of constructed facilities from feasibility to disposal. The WLCC assessment process takes into account the characteristics of the constructed facility, reusability,

sustainability, maintainability and obsolescence as well as the capital, maintenance, operational, finance, residual and disposal costs. The result of this stochastic assessment forms the basis for a series of economic and non-economic performance indicators relating to the various stakeholders' interests and objectives throughout the life-cycle of a project.'

The WLCC assessment components included in the above definition will serve as the guiding principles for this book. WLCC and risk assessment are but part of the overall management of the whole life-cycle of project processes that comprise the art and science of decision analysis. This book addresses the risk assessment-related aspects of decision making in the process of WLCC. The aim is to convey to the reader the fundamental principles of WLCC and risk assessment and the enveloping processes.

1.4 Risk and uncertainty in WLCC

In the previous section, attention has been drawn to the importance of dealing with risk and uncertainty in WLCC analyses. This importance is reflected in the new definition. However, this leads us to a salient point. Is there a difference between uncertainty and risk?

The authors believe there is a great difference. The terms risk and uncertainty are often used interchangeably, although a distinction can be drawn by noting that the concept of risk deals with measurable probabilities while the concept of uncertainty does not. An event contains an element of risk where a probability distribution can be defined. An event is uncertain when no probabilities can be developed concerning its occurrence. Risk refers to probabilities of errors in decisions and WLCC forecasts throughout the life-cycle of a project, or the probabilities of occurrence of events. Risk assessment deals with the likelihood and expectation of possible WLCC outcomes using probability concepts. If computed in terms of the probability of success or failure to achieve the return on investment, the risk is seen as an objective risk. It is an uncertainty when the probability cannot mathematically be indicated but there is enough knowledge to make a subjective judgement about the WLCC decisions. The more explicitly the risk is defined, the greater the possibility for the decision maker to have confidence in using the results of the WLCC analysis.

1.5 Subjectivity in WLCC

The issue of subjectivity and vagueness is also a very important facet of WLCC. Subjectiveness, vagueness and ambiguity (used interchangeably in this book) are different from randomness. Randomness deals with uncertainty (in terms of probability) concerning the occurrence or non-occurrence of an event. Subjectivity, on the other hand, has to do with the imprecision and inexactness of events and judgements, including probability judgements. Many WLCC decision problems involve variables and relationships that are difficult, if not impossible, to measure precisely. For example, probability judgements about issues like inflation, operation costs, etc. are not always precise in WLCC and often cost analysts use subjective expressions to express their probability judgements. This applies to probability judgements as well as the costs and benefits in many WLCC decision problems. The requirement for high levels of precision may cause WLCC models to lose part of their relevance to the real world by ignoring some of the relevant decision attributes because these variables are incapable of precise measurement or because their inclusion may increase the complexity of the models. Hence, the key to successful WLCC and risk assessment is to build models that require little information – no more than the users can provide. This is a challenge, but it is a challenge that is addressed through the chapters of this book.

1.6 Summary

In this chapter we have looked at the evolution of WLCC and introduced some of the basic principles behind the technique. A working definition of WLCC is proposed, based upon the results of a survey, and we have also briefly introduced the importance of considering risk, uncertainty and subjectivity. In the following chapters we will look in closer detail at the techniques and procedures that are commonly used in WLCC modelling and how these techniques can be modified to cope with risk.

Dealing with risk and uncertainty in WLCC should be the cornerstone of the analysts' approach to WLCC decision making. The uncertainty of forecasting has always been a key problem with practitioners, so by providing information and quantifying the risk element, stakeholders should be more confident in the information that WLCC can provide.

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