The nature of 'systems', and some early systems contributions to modern project management [1]

By Alan Stretton

INTRODUCTION

I had been working in project management (PM) environments in the construction industry for some twenty years before coming across Cleland & King's classic 1968 book *Systems Analysis and Project Management.* This was the first time I had seen a connection made between project management and 'systems''. However, this particular type of connection simply did not equate with my own experience in the construction industry, and thence did not appear to be particularly relevant to my work at the time.

Then, a decade later, along came another classic project management book which included 'systems' in its title, namely Kerzner's 1979 *Project management: A systems approach to planning, scheduling and controlling*. Further, in addition to having 'a systems approach' in its title, Kerzner asserted that "… project management is an outgrowth of systems management" (p.13). Moreover, similar assertions have also been made by many other authors. For example, Yeo 1993:111, said that, "The practice of project management has its origin in systems analysis and systems engineering".

Now, these are very specific assertions that project management originated in, or is an outgrowth of, systems management. However, of course, this is simply not the case. Many writers have pointed to ancient projects such as the Giza pyramids, Stonehenge and a myriad others, which would certainly be classed as projects in most modern definitions – although Morris 2013:12 discusses them in a chapter entitled "Project management before it was invented". Most recently, we have an in-depth contribution from Patrick Weaver 2022 in this journal on the evolution of project management, in which he proposes nine historic classifications of project management from around 9500 BC to the present day. Six of these are prior to the 20th century.

At a much more modest level, in Stretton 2023e I discussed some general management and associated antecedents of modern project management, most of which also precede the systems era. The latter is generally dated from around the early 1960s – although, as we will see, there were some isolated systems influences prior to that.

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Now, continuing with the subject of systems, after the above quotation, Yeo 1993 then went on to say that the Systems Engineering approach "….has provided the conceptual basis for the development of the many modern project-management concepts, procedures and techniques that are familiar today".

Here we move into different territory. There is no doubt whatever that systems approaches have been the source of many of the more modern techniques used in project management. Yeo and other writers, including Morris 2013 and Morris 1994 have listed many such examples, which will be discussed in more detail later in this article.

However, as I tried to get a better understanding of what 'systems' were about, I found substantially different interpretations of their nature in the project management literature – in short, 'systems' tended to mean different things to different people. It appeared to me that 'systems' approaches were probably somewhat pluralistic (not unlike project management?), which made it an even more difficult subject to get my head around. It was not until I came across Checkland 1981 that I began to get a better overall picture of the nature of systems.

The first major sections of this article will summarise my derived understanding of the nature of systems and the systems movement, and its earlier evolution. As just indicated, I will mainly draw on Checkland 1981, and adopt his seven primary activity groups as the reference points for ensuing discussions.

We will first look briefly at the theoretical development of systems thinking, which is illustrated with a time-lined summary of some key developments. We then turn to 'problem-solving' applications of systems thinking to real-world problems, which evidently evolved independently of the theoretical systems development.

Here we will distinguish between *hard* systems and *soft* systems, before going on to look in more detail at the two main components of hard systems, namely *systems analysis* and *systems engineering*. Systems analysis evidently derives from Operational Research (OR) work developed during and after World War II. Systems engineering can be viewed as its corresponding application activity.

These two primary systems activities have been particularly important in the early development of project management in certain industries in the USA, and we will look at five such cases, which include the aircraft industry, the development of ballistic missiles in two contexts, work in the US Department of Defense (DoD) under Robert McNamara, and NASA's Apollo program. Many of the techniques developed in these sectors, and particularly the DoD, have become common-usage items in wider project contexts.

We start with an overview of the nature of 'systems'.

AN OVERVIEW OF SYSTEMS

The systems approach

'Systems' tend to mean different things to different people. For example, Cleland & King 1968:19 says, in introducing *systems analysis,*

> At the outset, however, one should recognize that a semantic "jungle" exists; I.e. different people use different terms to express the same thing. For example, many managers and analysts use the terms "systems analysis", "operations research", "operations analysis", "cost-effectiveness analysis", etc. synonymously.

In the following, I am going to use the definitions and descriptors of Checkland 1981, whose contributions to systems thinking appear to be based on more thoroughly researched historical materials than any other writers I know of.

> **System:** The central concept 'system' embodies the idea of a set of elements connected together which form a whole, this showing properties which are properties of the whole, rather than properties of its component parts. (p.3)
>
> **Approach:** An *approach* is a way of going about tackling a problem. (p.5)
>
> **Systems approach:** An approach to a problem which takes a broad view, which tries to take all aspects into account, which concentrates on interactions between the different parts of the problem. (p.5)

Checkland 1981:5 goes on to point out that the systems approach is a mega-discipline whose subject matter can be applied within virtually any other discipline. In this article we will be primarily concerned with its historic relevance to the discipline of project management. But first we look briefly at the systems movement at large.

The systems movement

Checkland 1981:95 mapped seven groups of activities within the systems movement, as indicated in Figure 1 below.

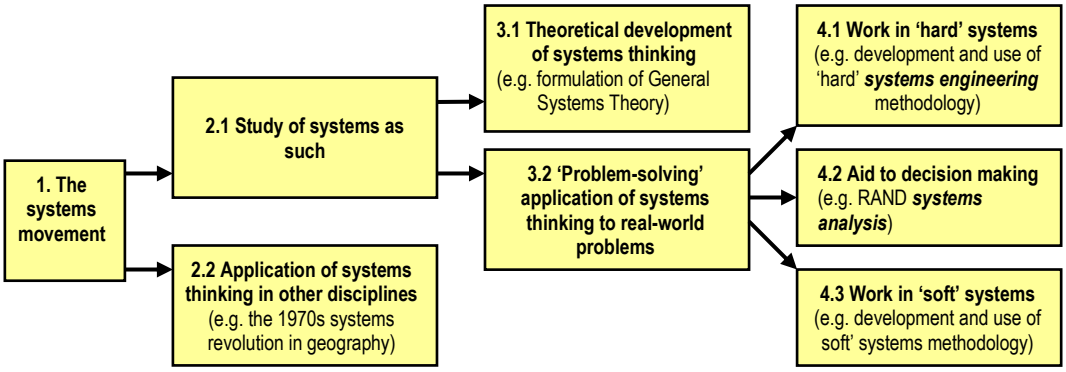


Figure 1. Seven activities within the systems movement. Adapted from Checkland 1981:95

I will use this model to discuss its two mainstream groups of activities, namely the theoretical development of systems thinking on the one hand, and the 'problem-solving' application of systems thinking to real-world problems, with its three component activities, on the other.

Theoretical development of systems thinking

3.1 Theoretical development of systems thinking
(e.g. formulation of General Systems Theory)

Ludwig von Bertalanffy developed General Systems Theory (GST) in the 1930s in a biological context, and in the mid-1940s generalised GST into systems in general. He helped found the Society for General Systems Research in 1954.

I have attempted to represent these basic developments in the following time-lined figure, which broadly indicates when these activities were initiated.

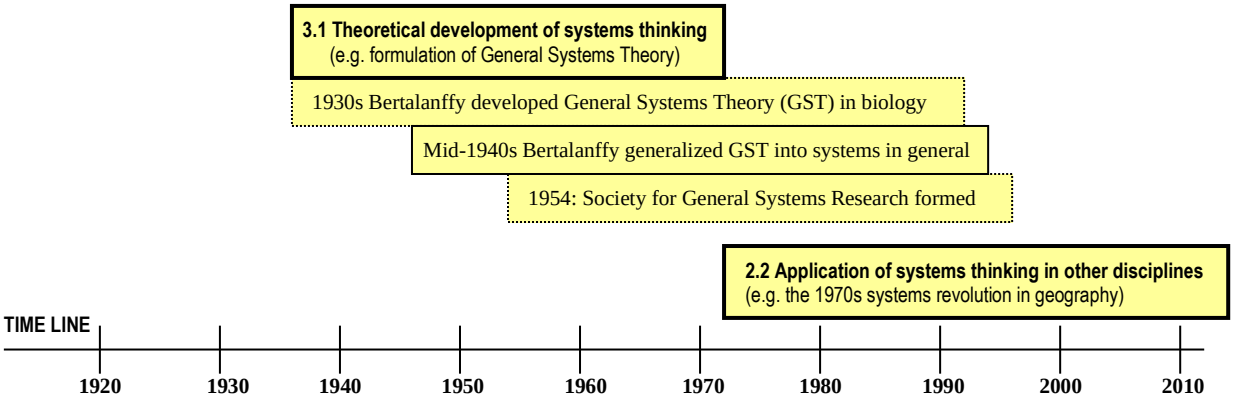


Figure 2. Illustrating the theoretical development of systems thinking, and an application

It can be seen that I have also made provision for another Figure 1 activity group, namely *3.2: Application of systems thinking to other disciplines.* The example is described by Checkland 1981:94 as "the Cambridge geographers' re-writing of geography from a systems point of view".

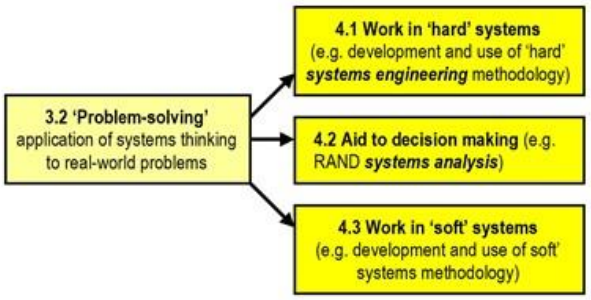
I do not know of other such applications, but they do not appear to include project management, whose systems connections originally derived from other sources, as discussed in the following sections.

'Problem-solving' application of systems thinking to real-world problems

Historically, the first two components of this sector, namely *4.1: Work in hard systems*, and *4.2: Aid to decision making* In Figure 1, developed independently of *3.1: Theoretical development of systems thinking.* In particular, as Checkland 1981:95 notes (in relation to Figure 1 above):

> Significantly missing is an arrow from 3.1 to 4.2; on the whole the RAND/OR/ management science world has been unaffected by the theoretical development of systems thinking, it has been *systematic* rather then *systemic* in outlook, ….

Before further discussing the three components of this 'problem solving' sector (in the text boxes 4.1 to 4.3 on the right) in more detail, we need to examine and explain the difference between hard systems (text boxes 4.1 and 4.2) and soft systems (text box 4.3).



Distinguishing between hard systems and soft systems

Hard systems

Checkland 1981:316 defines a 'hard' problem as:

> A problem, usually a real-world problem, which can be formulated as the search for an efficient means of achieving a defined end.

Although only 4.1, which includes *systems engineering*, is specifically nominated as a 'hard' system, 4.2, which includes *systems analysis*, is also classified as a hard system. As Checkland 1981:15 puts it.

> The thinking embodied in 'systems engineering' and 'systems analysis' is essentially the same. Analysis of many different accounts of these activities shows that they all assume that problems can be formulated as the making of a choice between alternative means of achieving a known end. The belief that real-world problems can be formulated in this way is the distinguishing characteristic of all 'hard' systems thinking.

In other words, clear and definite objectives can be defined in the early problem-solving stage, and alternative means of achieving the objectives can be found, and evaluated.

Soft systems

On the other hand, soft systems are concerned with ill-structured or un-structured problems. In this context, Checkland 1981:155 defines these kinds of problem as

> A problem relating to real-world manifestations of human activity systems is a condition characterized by a sense of mismatch, which eludes precise definition, between what is perceived to be actuality and what is perceived might become actuality.

Checkland goes on to say, "They are conditions to be alleviated rather than problems to be solved". This appears to be the main domain of *soft systems methodology.*

The historical connection between systems and project management hinges strongly around hard systems, in the form of systems analysis and systems engineering, as now discussed in more detail

SYSTEMS ANALYSIS AND SYSTEMS ENGINEERING

4.2 Aid to decision making (e.g. RAND ***systems analysis)***	**4.1 Work in 'hard' systems** (e.g. development and use of 'hard' ***systems engineering*** methodology)

Some definitions/descriptors

The following definitions/descriptors come from Checkland 1981:138

> ***Systems analysis*** is the systematic appraisal of the costs and other implications of meeting a defined requirement in various ways.
>
> ***Systems engineering*** comprises the set of activities which together lead to the creation of a complex man-made entity and/or the procedures and information flows associated with this operation.

Origins of systems analysis – Operational Research (OR)

There appears to be widespread agreement that *systems analysis*, and thence *systems engineering*, derive from Operational Research (OR) activities, which originate from just prior to World War II. Checkland 1981:73, quotes the OR Society's official definition of OR, as follows.

> **Operational Research (OR)** is the application of the methods of science to complex problems arising in the direction and management of large systems of men, machines, materials and money in industry, business, government and defence, The distinctive approach is to develop a scientific model of the system, incorporating measurements of factors such as chance and risk, with which to compare the outcomes of alternative decisions, strategies or controls. The purpose is to help management determine its policy and actions scientifically.

Evidently OR had its origins around 1937, when British scientists were asked increasingly to assist military executives in learning how to use their newly developed radar to locate enemy aircraft. By 1939 this had become a formal activity. OR blossomed during WW2, in both the British and American armed forces, and is credited in improving many military operations in addition to radar, several of which are listed in Morris 1994:10.

After the war some OR activities remained in the military, whilst others migrated to industry. The most prominent organization associated with the latter was the RAND Corporation, which, after contracting to the Douglas Aircraft Company from the end of

WW2, separated from Douglas in 1948, and became an independent non-profit advisory corporation. Checkland 1981:134 records that,

> In the immediate post-war years …..there emerged what a historian of RAND Corporation described as "a broader and more refined discipline [than OR] – "systems analysis".

As Checkland 1981:135-6 goes on to observe,

> During the 1950s the pattern of RAND-style 'systems analysis' became clearer. The work done consisted of broad economic appraisal of all the costs and consequences of various alternative means of meeting a defined end.

From systems analysis to systems engineering

I believe that Yeo 1993 expresses the relationship between *systems analysis* and *systems engineering* better than most. He defines *systems analysis* as a systematic approach that deals with the problems of the identification and selection of alternative proposals, which is pretty much the same as Checkland, and many other writers. He then says that *systems engineering*

> [takes] the decision on the best alternative [from the systems analysis] as given, and concentrates on the implementation of such a proposal.

I have adopted these understandings of the nature of *systems analysis* and *systems engineering* in the following discussions on connections of systems approaches with project management.

SOME EARLY CONNECTIONS FROM SYSTEMS ANALYSIS/ENGINEERING TO PROJECT MANAGEMENT

1953-54: Martin (Marietta) aircraft company

In the first article of this series, systems were first mentioned in the following quotation from Morris 2013:28, which was concerned with new arrangements regarding delivering projects for the US Air Force.

> McDonnell began using the title of project manager in 1953, the project manager's prime responsibility being organisation and staffing. More significantly perhaps, Martin has a claim to have established the first matrix organisation, creating in 1953-54 "a number of miniature companies, each concerned with but a single project. The project manager exercises product control". All functions, from design to manufacturing and distribution, were covered: systems analysis being used to determine requirements, systems engineering on design, and systems management on integration.

This indicates that the project manager used systems analysis to determine requirements, plus systems engineering on design, and integration of these systemic activities.

From 1954: Atlas intercontinental ballistic missile program

Morris 2013:28 comments that, of all the forces influencing the emergence of project management, the most significant was the USAF's management of Atlas, America's first ICBM (intercontinental ballistic missile).

In particular, Morris noted that the man appointed to head up this effort, Brigadier Schriever, had a strong interest in the newly emerging systems approaches to planning and engineering. Shriever felt that the complexity of the program merited a 'systems integrator' function that would sit between the USAF and the contractor, Convair, performing systems engineering and providing technical support to the program.

Later, in 1955, Schriever was effectively given autonomous command of the Atlas program. Morris 2013:30 quotes from Johnson 1997 as follows.

> "These new procedures represented the first full application of project management in the air force, where the project manager had both technical and budget authority for the project".

The success of this program is well documented.

From 1956: US Navy, Special Projects Office (SPO) – Polaris fleet ballistic missile

Morris 1994:25 notes that, even more than Atlas, Polaris elevated the authority of 'the Program' within the organization as opposed to the traditional functional organization. A new organization, the Special Projects Office (SPO), under the command of Admiral Rayborn, was created in November 1955. Morris 1994:27 also notes that the systems management function within the Polaris program was not formalized as clearly as in General Schriever's Division within the USAF.

> Main responsibility for systems engineering rested with the Chief Engineer in the SPO's Technical Directorate, whose task was to establish systems boundaries and monitor interface relationships.

Unlike Atlas, Polaris developed a management control procedure, the Program Evaluation & Review Technique (PERT) in 1957. This was an event-oriented network scheduling system. To cope with substantial levels of uncertainty about estimated times for the activities undertaken to achieve each event, each group of activities was represented as a three-point probability distribution (pessimistic, likely, optimistic). Probabilities for meeting overall scheduled project duration times were then calculated, critical events identified, and rescheduling undertaken as required.

Morris 2013:34 noted that PERT never quite fulfilled its promise on Polaris, but that Admiral Rayborn used PERT "as a tool to manage his external environment", particularly lauding it to Congress.

From 1960: US Department of Defense (DoD) – Secretary Robert McNamara

In 1960 Robert McNamara was appointed as the US Secretary of Defense and brought with him what Morris 1994:39 described as his "enthusiasm for systems management and management science". Morris 2013:36 says,

> McNamara was an OR enthusiast and a great centraliser. He used systems analysis extensively to organise and manage the Department of Defense, re-organising many aspects of operations, intelligence, communications, development and supply. Upon entering office for example he introduced the Program Planning and Budgeting System (PPBS) to help produce long-term, program-oriented budgets and he mandated several systems-based practices such as Life Cycle Costing, Integrated Logistics Support, Quality Assurance, Value Engineering, Configuration Management, and the Work Breakdown Structure (WBS).

Morris goes on to note that these tools and techniques have since become core to project management as a discipline.

From 1961: NASA Apollo program – Landing men on the Moon

Morris 2013:37 notes President Kennedy's proposal that "this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to Earth", and goes on to observe that

> The resulting Apollo program has several lessons for us in tracing the evolution of the discipline of project management: its strategy and targets, matrix management, configuration management, and the cost/quality relationship, but above all, Apollo was the great sales program for the new discipline of systems project management.

Later, Morris notes that although Apollo was so successful, the limits of systems project management had already been reached. Beyond the 1960s I do not know of any further historical contribution from systems theory to project management. There have been some comparatively recent articles connecting 'soft' systems and projects, but this is still work in progress, and therefore not part of this historical review.

Summarising these early connections

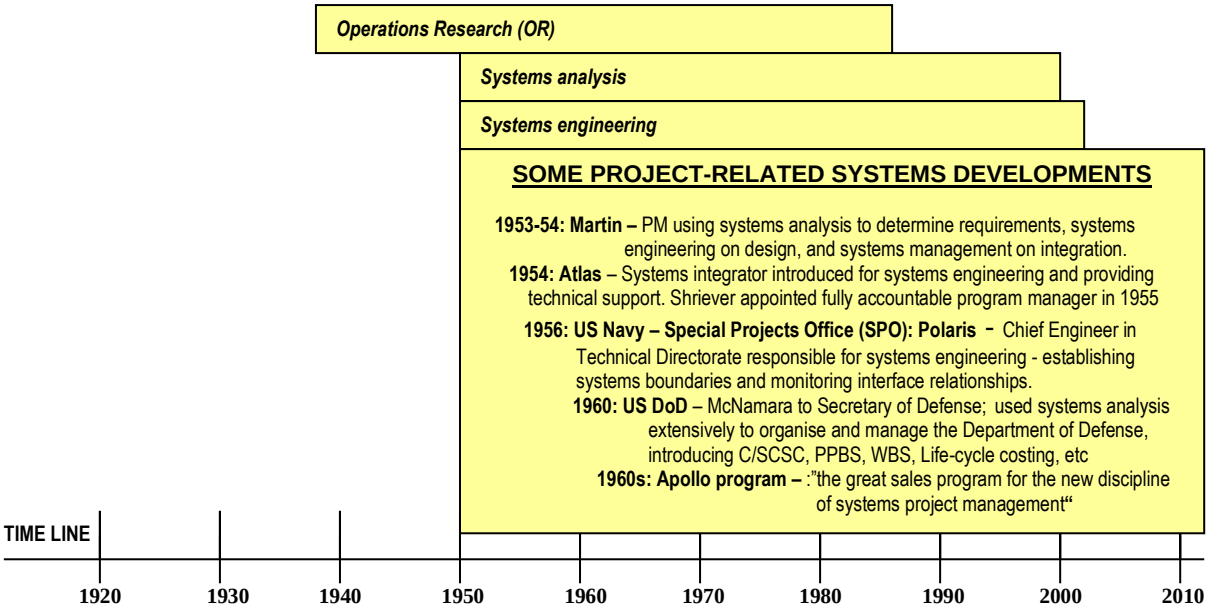


Figure 3. Summarising some applications of systems analysis/engineering in project management

SUMMARY/DISCUSSION

The rather substantial introduction to this article outlined the background for my undertaking this short investigation of the nature of 'systems', and some early systems contributions to modern project management.

In view of the fact that 'systems' tends to mean different things to different people, we first overviewed the systems movement as represented in Checkland 1981, including a model of its seven primary activity groups, which were used as the reference points for following discussions. This model had two main streams – namely the theoretical development of systems thinking, and the 'problem-solving' applications of systems thinking to real-world problems.

In the latter context we distinguished between *hard* systems and *soft* systems. Hard systems include systems analysis and systems engineering. We looked first at the origins of systems analysis, which derives from Operational Research (OR) work developed during and after World War II; and then at the application activity, systems engineering.

These two primary systems activities have been particularly important in the development of project management in certain industries, notably in the USA, where we look at five particular cases. These included the aircraft industry, the development of ballistic missiles in two contexts, work in the US Department of Defense (DoD) under Robert McNamara, and NASA's Apollo program. I indicated the start of most of the above system-related developments in the time-scaled Figure 3.

Examples of techniques developed in the above sectors (particularly in the DoD), as cited in the two Morris references and Yeo 1993, include *Integrated Logistics Support, Configuration Management, Earned-value methods for progress measurement, Value Engineering, Value analysis, Quality Assurance, Systems procurement procedures, Responsibilities assignment matrices, Life Cycle Costing,* and various more detailed control processes, such as *PERT/Cost, PPBS, and C/SCSC.* Many of these techniques have come to be used in other and broader project contexts.

In summary, most of the contributions made from the 'systems' domain have added very substantially to the arsenal of project management techniques, and also to systematic (rather than systemic) approaches to project management processes.

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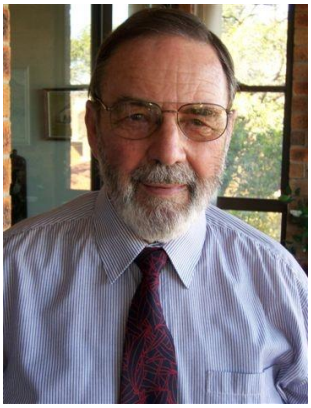
About the Author



Alan Stretton, PhD

Faculty Corps, University of Management and Technology, Arlington, VA (USA)

Life Fellow, AIPM (Australia)

Alan Stretton is one of the pioneers of modern project management. He is currently a member of the Faculty Corps for the University of Management & Technology (UMT), USA. In 2006 he retired from a position as Adjunct Professor of Project Management in the Faculty of Design, Architecture and Building at the University of Technology, Sydney (UTS), Australia, which he joined in 1988 to develop and deliver a Master of Project Management program. Prior to joining UTS, Mr. Stretton worked in the building and construction industries in Australia, New Zealand and the USA for some 38 years, which included the project management of construction, R&D, introduction of information and control systems, internal management education programs and organizational change projects.

Alan has degrees in Civil Engineering (BE, Tasmania) and Mathematics (MA, Oxford), and an honorary PhD in strategy, programme and project management (ESC, Lille, France). Alan was Chairman of the Standards (PMBOK) Committee of the Project Management Institute (PMI®) from late 1989 to early 1992. He held a similar position with the Australian Institute of Project Management (AIPM) and was elected a Life Fellow of AIPM in 1996. He was a member of the Core Working Group in the development of the Australian National Competency Standards for Project Management. He has published 250+ professional articles and papers.

Alan Stretton can be contacted at alanailene@bigpond.com.au.