The Application of Dynamic Control Feedback Loops to the Problematic Issue of Controlling 'as Designed' Compared to 'as Built' on Construction Projects

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SUMMARY

The objective of this paper is to explore the problematic issues of ensuring that the design and construct process is effectively and efficiently controlled. Control is one of the key functions of management and it is imperative that a functioning control system is deployed on any construction project. However, the objective further seeks to provide advocated solutions to the noted problems. As first designed is not usually as built, variations and/or late instructions will exist. Thus feedback loops operating with short cycle times and detailed information are vital if quality is to be assured. Within the paper the results of original work appertaining to a valid methodological approach for ensuring the monitoring and delivery of a quality structure are presented. This methodology can be adopted or adapted for other construction projects. In conclusion the paradigm presented within the text would prove very useful in addressing this key theme of the symposium, i.e. overcoming the difficulty of monitoring and controlling the bridge between design and build.

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1. INTRODUCTION

Control is concerned with the effective and efficient utilisation of resources in the attainment of previously determined objectives (or plan). This plan can take many forms. For example, it could be the design of a structure, a contract programme or a financial budget, the design (plan) being the method to be deployed in order to achieve the predetermined objectives.

Control is exercised by the feedback of information on actual performance when compared with the predetermined plan and, therefore, planning and control are very closely linked. Control is the activity which measures deviations from planned activities/objectives and further initiates timely, effective and efficient corrective actions.

Thus we require a system for monitoring and controlling the design process through to on-site construction activities. Changes to the original plan have to be clearly identified and acted upon in a timely fashion. This paper addresses this critical issue.

The system should be robust, simple to operate, relevant and with lines of responsibility clearly articulated. A workable system would provide recognition of the nature of design as being a non-mechanical process. In addition it should recognise and consider any workload it may impose on smaller practices, in particular those where financial margins are tight, workloads variable and problems of control more likely.

2. DESIGN AND CONTROL

The designer has to be able to provide a specification for design from the client's needs. The design aspect must be covered by the quality system. Within an organisational structure responsibility and authority for the design should be clearly defined. Any design project requires planning and the plans must include the identification of responsibility for each design, development activity and opportunities for feedback loops.

An effective communication system must exist within organisations. The communication system has to enable the monitoring and control of the assigned activities. It may be necessary during the design process to deviate from specification. Should this be the case permission from the originators of the specification must be obtained and documented. Design verification has to be an ongoing process with formal design reviews. These reviews are performed in order to ensure that the objectives set in the specification are achieved and design review procedure changes may be sought and authorised. Architectural practices

should have systems in place for this process within the individual organization but it is in the handing over of control from design to construction that failures can occur.

Thus a document control system is a very important aspect for ensuring that design and construction are linked and controlled. It should ensure that the use of unauthorised or out of date documents should not be possible. The key to effective quality documentation is ensuring that it is brief whilst covering the essential points. It is most important that procedures reflect actual working practices. The scope of any document control process should cover the approval, issue and modification of all documentation and data related to the project but equally, it must be relevant to those charged with the responsibility.

Each section of a quality system should have its own 'Revision Control System'. The front sheet of every section indicates and lists the 'Revision History' which covers:

- Revision number
- Revision details
- Date
- Approved by
- Parties informed

The revision number of each section should be marked on the procedure and each section issued to (company) relevant personnel recorded in the 'Quality System Log'. (Appendix 1 provides an example of the headings suitable for a Quality System Assignment Log).

All contract specific documentation should have a contract specific stamp (see Appendix 2 for example) endorsed on the front sheet and the master copy will be retained in the job file. Each job file should contain a Contract Specific Document Distribution List (see Appendix 3 for example). Issuing of copies of these documents will be recorded on this list. All such documents must be returned at the request of the Project Manager (or whoever is charged with this responsibility).

It is important that a register of approved reference documents is maintained, including revision numbers. All such documents need to be approved by the Project Manager and the front sheet endorsed with the 'Approved Reference Data' stamp. (See Appendix 4 for example of contract specific document distribution list and Appendix 5 for approved data reference stamp).

The document distribution list has to be completed each time a revised document is issued and the old copies withdrawn and replaced. It is good practice to produce a 'Document Approval Matrix'. This will clearly define the document and responsibility for approval (see Appendix 6 for example).

The above processes are incorporated within a Quality Assurance System. However, the Quality Assurance System itself needs to be monitored and refined. In order to monitor and

control either the design process or the whole project, use can be made of the Deming Control Cycle.

2.1 Deming Control Cycle

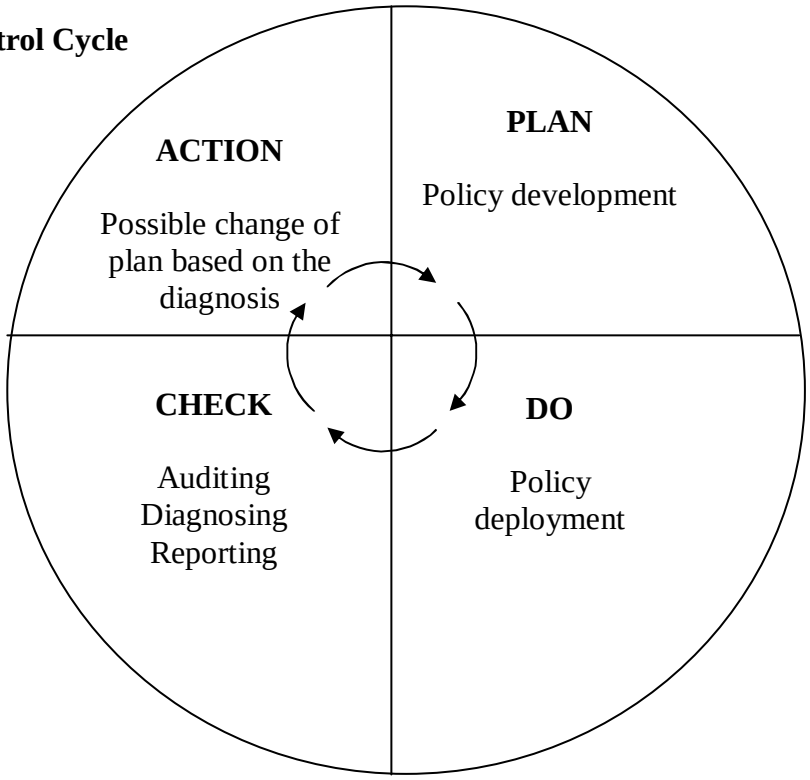

Figure 1: The Deming Plan, Do, Check, Action (PDCA) Cycle

(McCabe 1998, p. 33)

In order to have control the Deming Control Cycle should be employed as depicted in Figure 1: The Deming Plan, Do, Check, Action (PDCA) Cycle. Two issues are of vital importance. First, 'Cycle Time' - how long does it take for information to circulate around the loop. Secondly, the quality of the information in the loop. High quality information circulating regularly leads to efficient and effective control.

Bounds et al (1994, p. 5) advocated "traditional approaches to management are inadequate for keeping up with changes". Increased global competition and improved communications have lead to greater customer expectations. Thus the link between design and as built is a vital component in stakeholder satisfaction.

What is required:

"is a way of managing an organisation to ensure the satisfaction at every stage of the needs and expectation of both internal and external customers, that is, shareholders, consumers of its goods and services, employees and the community in which it operates, by means of every

job, every process being carried out right, first time and every time".(Henderson Committee, 1992, cited by Latham Report)

Organisational activities should be based upon a drive for continuous improvement by establishing current best practice and building upon these sound foundations.
(Wiele van der, Dale and Williams, 1997)

This important point has been acknowledged and incorporated into the new BS EN ISO 9001:2000 Quality Management System. The new standard is now based upon the 'Deming' model of Plan, Do, Check and Act, shown in Figure 1. However the model has been adapted to better relate to construction activities. This is indicated in Figure 4: Deming Dynamic Control Loop Cycle (adapted).

- Plan: identify customer needs and expectations, set strategic objectives;
- Do: implement and operate processes;
- Check: collect business results, monitor and measure the processes, review and analyse;
- Act: continually improve process performance.

2.2 BS EN ISO 9001:2000

BS EN ISO 9001: 2000 now specifically requires organisations to ensure effective internal communication between functions regarding system processes and external communication with customers not only at the contract stage but also with respect to the provision of product information and obtaining feedback. Thus it addresses the design construct link issue.

The requirement to plan and operate the system to facilitate the achievement of improvement makes specific an option that was only previously implied. (BS I 2000). Thus, control of the stages of the design process and its document recording system can be monitored and improved if the Plan, Do, Check and Act cycle is deployed. The Deming Control Cycle has also been incorporated into the EFQM model within its RADAR development (see Figure 3: The Criteria Underpinning the RADAR Concept).

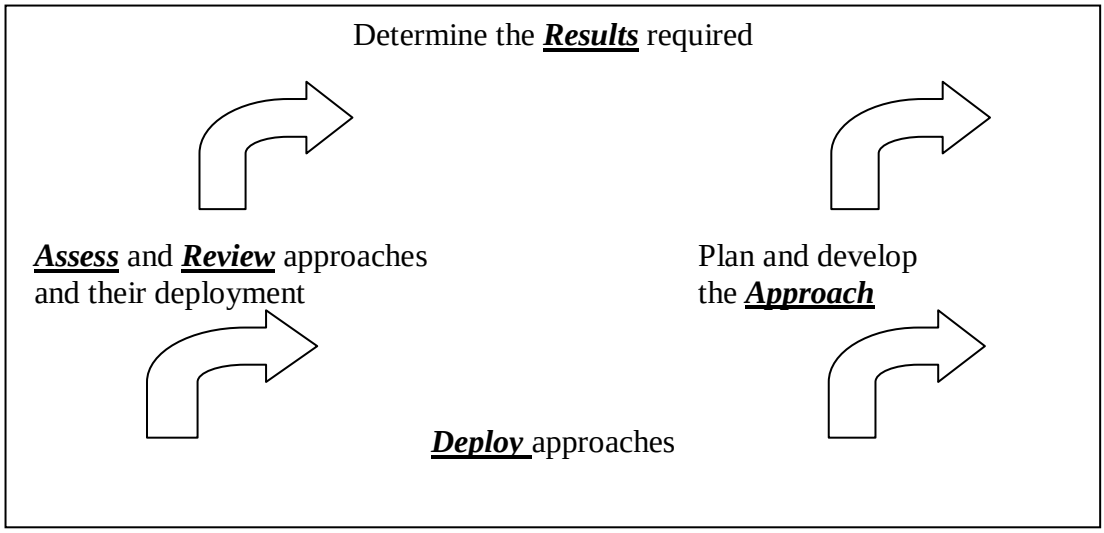

Figure 3: The Criteria Underpinning the RADAR Concept

3. RADAR LOGIC EXPLAINED

The RADAR logic states that an organisation needs to:

- determine the **R**esults the organisation is aiming for as part of its policy and strategy making processes. These include the performance of the organisation, both financially and operationally and the perception of its stakeholders;
- plan and develop an integrated set of sound **A**pproaches to deliver the required results.

Both the 'Results' and 'Approaches' elements related to the Plan stage of Deming's control cycle, see Figure 5. Matching of Plan, Do, Check and Act Cycle with RADAR.

- **D**eploy the approaches in a systematic way to ensure full implementation. The deployment is the 'Act' stage of Deming's Cycle.
- **A**ssess and **R**eview the approaches followed based on monitoring and analysis of the results achieved utilising ongoing learning activities. Based on this assessment, companies should identify, prioritise, plan and implement improvements where needed. (European Foundation for Quality Management 1999).

'Assess' and 'Review' cover the 'check' and 'act' components of Deming's Cycle.

The basic premise of both BS EN ISO 9001:2000 and the European Foundation for Quality Excellence Model is the concept of control as depicted in Figure 1. An appropriate management system must be built around the 'Quality of Service Provision' provided and a truly service focused quality system will have an in-built mechanism for the attainment of continued organisational improvement as evidenced in Figure 4.

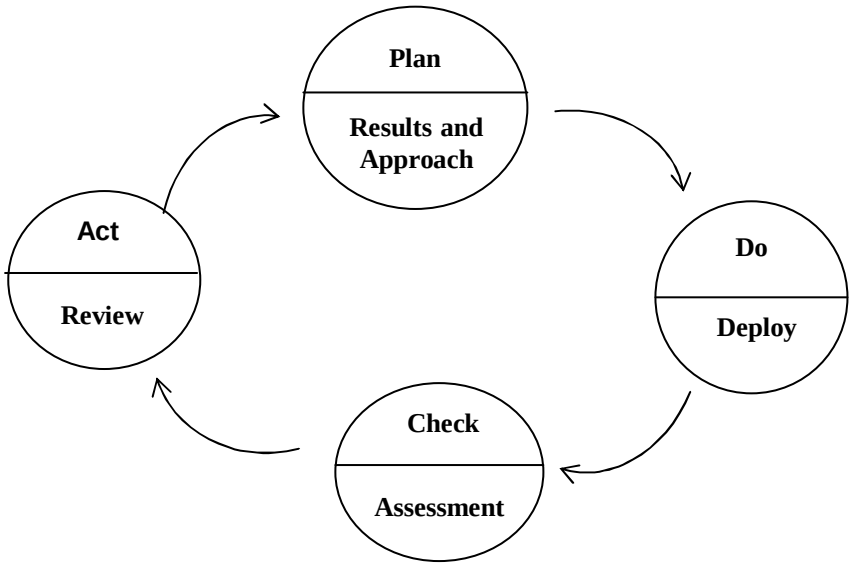

Fig 5: Matching of Plan, Do, Check and Act Cycle with RADAR

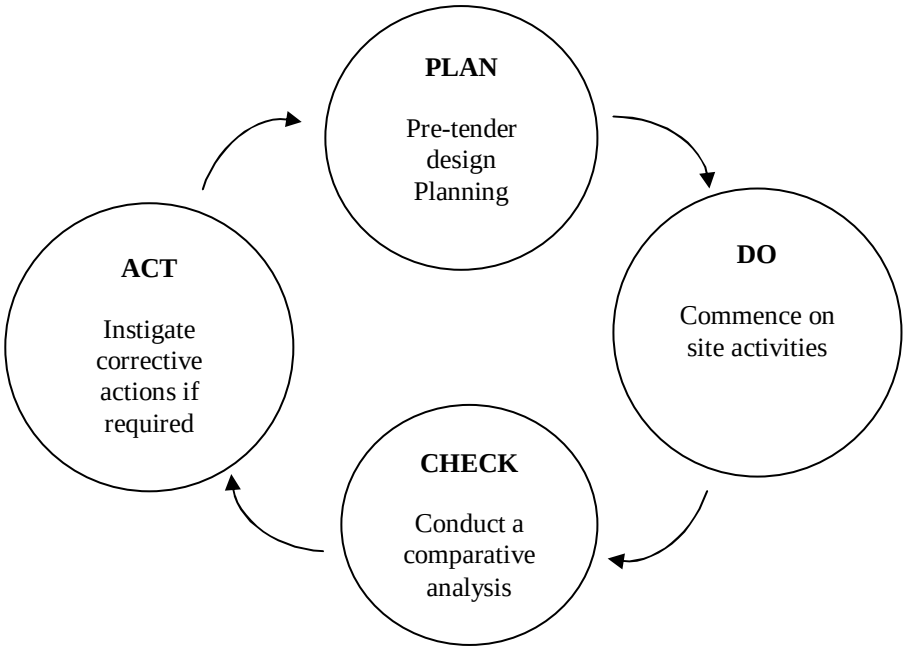

Fig. 4: Deming Dynamic Control Loop Cycle (adapted)

With specific reference to the design process and ensuring that alterations to design are monitored and controlled, one does not have to be certificated to BS EN ISO 9001:2000. It is in fact the basic concept that is important, i.e., that the four stages of Plan,Do, Check and Action are incorporated into any quality system and, further, that high quality information circulates at regular timely intervals. One must not forget that it is impossible to have

efficient and effective retrospective corrective actions. Unfortunately this tends not to be the case with controlling the design process and its link to the construction phase.

Many problematic issues such as the reliance on unresolved or unsuitable details (too complex for the purpose or standard details used inappropriately), inefficient use of materials and components due to lack of sufficient research or reliance on 'favourites' develop because the control system is not effective. An effective control system could ensure that these issues are addressed at an early stage particularly through the input of those responsible for on-site control. This brings into question the responsibility of controlling the design process.

The control cycle, Figure 5, suggests that an organisation only monitors its original plan (design) and instigates corrective actions based upon collected data and a reflective comparative analysis. But where is the drive for improvement of organisational performance? This aspect can only be attained if the comparative analysis data is used as 'feed-forward information'.

Within Figure 5 the design documentation will have to meet client's requirements. Thus quality objectives should be part of any project quality plan. The inclusion of, or referral to, a schedule of all applicable drawings and specifications should also be included within the quality objectives. Further the project quality plan must include how document control will be dealt with.

Accurate and up-to-date information is essential for meeting specified requirements. The PQP should incorporate the company's document control procedures. Drawing registers should be maintained and an issue and receipt system implemented. The withdrawal of obsolete drawings and information has to be recorded and notified to all relevant personnel.

4. CONCLUSIONS

This paper has provided a valid methodology for introducing and maintaining an efficient and effective document control system. However, the importance of monitoring and trying to continue to improve the control process has also been advocated. An example of the Plan, Do, Check and Act three dimensional model is given for design practitioners to follow (figure 6). Figure 6 further links the design and construction phases into a holistic construction process. Thus the problematic issue of controlling design and as built can be resolved to all stakeholders satisfaction.

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APPENDIX 1

Quality System Section Assignment Log					
Assigned To	**Date of Issue**	**Controlled Document**		**Revision Level**	**Date withdrawn**
		Yes	No		

APPENDIX 2

Contract Specific Stamp	
This document is specific to job number..... **It must <u>not</u> be considered relevant to any other job**	**Revision Number.....**
	Date of Issue.....
	Authorised by.....

APPENDIX 3

Document Distribution List

Document Title_____

Assigned to	**Location**	**Date of Issue**	**Date withdrawn**

APPENDIX 4

Contract Specific Document Distribution List				
Document Title	**Revision**	**Assigned to and location**	**Date of issue**	**Date returned**

APPENDIX 5

Approved Reference Data Stamp
Reference Data
Approved Copy Number.....
Revision Number.....

APPENDIX 6

Document Approval Matrix		
Document Description	**Master held by**	**Original and Revision Approved by**

Too often systems fail, sometimes leading to significant loss of life, fortunes and confidence in the provider of a product or service. It was determined that a simple and useful tool was needed to help in the analysis of interactions of groups and systems to determine possible unexpected consequences. The tool didnâ€™t need to provide every possible outcome of the interactions but needed to provide a means for analysts and product/service development stakeholders to evaluate the potential risks... Cost Control Overview. The control of construction costs takes place during every phase of the construction project. See Figure 1-1, Cost Control Cycle. The estimate is generated during the preconstruction phase.Â One example of a control system is the heating control system that can be found in a rustic cabin. The wood stove creates heat (corrective action) to maintain the interior temperature (element to be controlled) of the cabin. Feedback is accomplished by the seat-of-the-pants method.Â Control systems are used to manage the costs on construction projects. The element to be controlled is the project cost. Project management gathers actual costs (feedback) and compares them to the project budget. See Figure 1-5, Construction Cost Control Cycle. Applications of feedback control to musical instrument design. A dissertation submitted to the department of electrical.Â However, compared to the development of traditional music over several centuries, the development of computer music has been so quick and so eager that the quality of the physical interaction between the performer and the instrument has deteriorated, both to the detriment of the performance and its reception by the audience.Â I did not plan for the instrument designs outlined in this thesis to conform to the notions of Physical Interaction Design. I merely set out with the idea of enhancing the musicianâ€™s interaction with the instrument by providing improved force feedback. A control system in which the control action is totally independent of output of the system then it is called open loop control system, which is also called as Manual control system. example-Electric Hand Drier, Bread Toaster, Automatic Tea/Coffee Maker. Advantages of Open Loop Control System. Simple in construction and design.Â Construction: They are relatively more complex in construction and hence it adds up to the cost making it costlier than open loop system. Since it consists of feedback loop, it may create oscillatory response of the system and it also reduces the overall gain of the system. Stability: It is less stable than open loop system but this disadvantage can be striked off since we can make the sensitivity of the system very small so as to make the system as stable as possible.