

Implementing Lean in construction:

Lean tools and techniques – an introduction

Richard O'Connor, Transform Business Improvement Ltd

Brian Swain, Brian Swain Ltd

Feedback

CIRIA and the project steering group welcome your feedback on the documents in the Lean series.

However, before reading this guide, and without reference to the contents list, please write down five areas or specific questions that you are hoping the guide will help you with.

We invite you to list these points, and the extent to which they have been covered, in the Lean questionnaire, which can be found at: www.ciria.org/service/lean



Brian Swain Ltd

Implementing Lean in construction: Lean tools and techniques – an introduction

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Why read this guide?

Do you want to improve business organisation, performance, competitiveness and profitability? Would you like to raise project delivery performance in terms of quality, programme and cost? If you answered yes to any or all of these points, then you should read this guide.

This guide outlines the use of Lean tools and approaches that have been adapted, developed and applied successfully in the construction industry throughout the UK and across the world. Several key tools are presented. Each tool is described, pointers on where, when and how to apply are given and the benefits that typically result are listed. Simple case examples are included to outline where each tool has been successfully applied.

To maximise the gains possible on a construction project, Lean should be applied by all parties to all stages, aspects and activities of the end-to-end project cycle. However, this guide has been written to focus on the construction phase of a project. It intends to give the reader initial guidance on a series of Lean tools and techniques that can help you deliver tangible benefits to your business and in the way you deliver construction works and projects. Lean and the related tools really do deliver and we hope this guide motivates you to really 'go Lean'.

Background to topic

'Lean' in its simplest form means eliminating waste from every aspect of the work process while ensuring that value-adding activities are completed in the most efficient and time-effective manner. Lean has been successfully applied in all sectors of business, service and project delivery, resulting in improved performance in quality, time, cost and bottom line profit. Lean also helps organisations to develop their people, at the same time creating a culture of continuous improvement.

When used to improve the delivery performance of a construction project, ideally Lean should be applied right from the start of a project to help define efficient processes and practices, not only for the construction process but for pre-construction processes as well. Lean tools can also be applied to improve the delivery of specific aspects of a project and help in the recovery of a project that is already underway and requires improvement in performance. Whichever point in a project Lean is applied, there is now evidence to show that value for money can be optimised as Lean will help improve 'right first time' quality and improve cost and time performance.

CIRIA Lean guides

This guide is one of a series of publications and, together with an overview document, can be found at: www.ciria.org/service/lean

C725 Lean and BIM (Dave, B, Koskela, L, Kiviniemi, A, Owen, R, Tzortzopoulos, P)

C726 Lean and sustainability (Corfe, C)

C727 Lean benefits realisation management (Smith, S)

C728 Lean client's guide (Chick, G)

C729 Selecting a Lean consultant (Fraser, N)

C730 Lean tools – an introduction (O'Connor, R and Swain, B)

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Introduction

This guide presents an overview of the key Lean tools and activities that have proven to deliver real benefits to the performance and delivery of construction projects. It is not an exhaustive, step-by-step manual with detailed instructions for each tool. Instead each tool is introduced and sufficient detail provided to understand what it is, when and where to apply it and the associated benefits.

Many of the tools in this guide can be used in isolation to help resolve a specific issue or to make an improvement. However, the tools provide maximum benefit if they are used as part of a Lean end-to-end project delivery strategy and system of improvement for construction companies to develop their people, their supply chains and improving performance.

Lean has great synergy with collaborative working – the basis of establishing the truly integrated and high performing construction team. Project performance will be optimised where Lean processes and practices are integrated with effective collaborative working between all parties.

1.1 WHAT IS LEAN?

Lean is a term to describe an effective, high-performance method for managing organisations and delivering their core purpose in the most efficient and effective manner while continuing to develop for a sustainable future. Lean is an ethos, a way of doing business. It seeks to maximise the generation of customer value by driving out all forms of waste, ensuring ‘right first time’ quality, reducing timescales and minimising cost. Many Lean principles exist that describe some of the key elements of Lean thinking and its underlying theory. Five key principles are listed here, but to get a more in-depth understanding of the scope and breadth of Lean, the reader is directed to the 14 principles defined and followed by Toyota (see Liker, 2004).

The five principles of Lean and their relevance to construction projects are as follows:

Customer value: it is important to establish what the customer really desires in terms of ‘value’ outcomes or deliverables. For a construction project this might be, for example, a building that must meet specified design and functional performance criteria. The customer will also be interested in achieving the design specification at best ‘value’, which could include delivery on or before a defined date, ‘right first time’ quality, within budget, percentage cost saving (as per a pain-gain commercial process on an NEC form of contract) etc. Once defined, customer value should be the common focus for parties involved in the project and form the basis for project Hoshin objectives (see Chapter 2).

The value chain: also known as the ‘value stream’ and refers to identifying all processes required to deliver a product, service or project and then assessing how well customer value is being/will be delivered. In construction this relates to defining and challenging the end-to-end processes for a construction project with the aim of establishing processes that are efficient and waste-free. This requires eliminating anything that does not add customer value and ensuring that value-adding

activity is carried out in the most productive way. This is a useful way of thinking. If something is not valued by the client why spend resources doing it?

Make the value flow: the means achieving the best sequence and programme of work by ensuring balanced work, small batch production (eg breaking a work area into smaller work phases so that a trade can follow on a preceding trade more quickly, meaning that large areas/spaces do not remain dormant with no work being done), simultaneous working, removing things that delay and disrupt etc.

Pull: 'pull' refers to the action of only doing work activity in-line to the pull or demand of the customer. When related to a construction project this refers to synchronising construction activities to the needs of the customer (eg to an agreed time/pace of construction). The aim is to ensure that all parties align to an agreed programme where work activities are closely integrated in terms of time and sequence, and activities being carried out only when needed to assist a subsequent activity. This applies to all levels of planning and scheduling, and is a key principle underlying the Lean collaborative planning and project management technique (see Chapter 3).

Perfection: continually striving for perfection by practising continuous improvement. Look for and implement improved methods within a project, and performance improvement, lessons learnt etc from one project to the next.

1.2 WASTE

A key principle of Lean is the identification and systematic elimination of process waste from every stage of the value chain (see Figure 1.1). The work done to provide a product or service can be divided into three components:

- ▶ **value-adding (VA):** this is the work that changes the shape or nature of the product (or service) in a way that contributes to the final form that the customer is willing to pay for
- ▶ **essential non-value adding activities (ENVAs, or support activities):** these are the tasks that must be completed to enable the value-adding activity to be completed, but do not add value. For example, inspection does not add actual value but is necessary up to the point where a process can be improved so that inspection can be eliminated

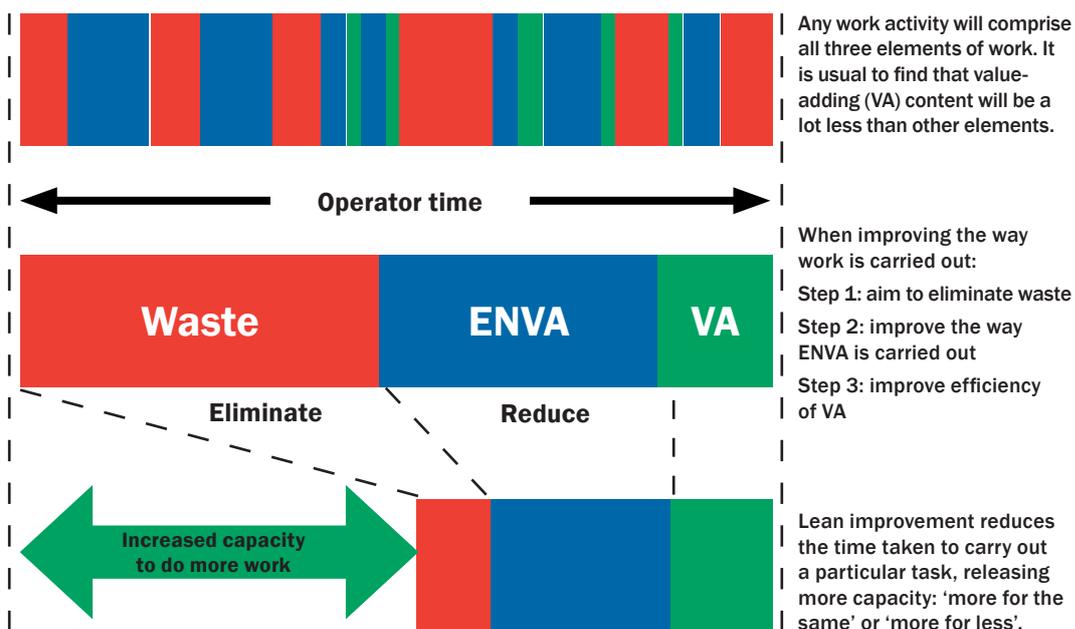


Figure 1.1 Eliminating waste

- ▶ **waste:** this is any other activity or event associated with carrying out a particular work activity. Waste can be viewed from two perspectives:
 - ▶ waste in the work itself (eg excessive walking, looking for tools and materials, and poor quality)
 - ▶ introduced or 'enforced' waste (eg waiting for information, materials not supplied) that has prevented work activity from being carried out.

1.2.1 The eight wastes

To help identify the level and type of waste within a process, eight categories of waste have been defined. It is common to see the first seven forms of waste represented by the acronym TIMWOODS:

- ▶ **transportation:** unnecessary movement and handling of goods
- ▶ **inventory:** poor planning and control of inventory leading to excessive stocks, shortages etc
- ▶ **motion:** excessive or unnecessary movement of people when carrying out work. This can be due to poor layout of tools, materials, plant etc in the workplace
- ▶ **waiting:** where resources (people and/or plant) are idle waiting for information, materials, people or access etc
- ▶ **over-production:** producing more than is required and/or ahead of time, which can introduce waste due to out-of-sequence works
- ▶ **over-processing:** doing more than is required to meet design requirements leading to excessive time and/or cost. For example, spending time to produce a level of quality that is higher than required, double handling of items, materials etc
- ▶ **defects:** non-'right first time' quality requiring rework, introducing extra time and cost
- ▶ **skills misuse:** the waste of not effectively tapping into the expertise and knowledge of people.

A ninth waste, the waste of 'making do' has been proposed by Koskela (2004). It is argued that in construction many of the issues and wastes that introduce inefficiencies into many projects go unchallenged.

These wastes will be found in all areas of an organisation and/or project. They arise from poorly defined systems, processes and practices resulting in excessive time and cost. The level of waste associated with construction projects has been reported to be as much as 50 per cent (Egan, 1998), and is attributed to inefficiencies through design, mobilisation, construction and maintenance activities. By taking the time to stand back, review and challenge the way things are organised, planned and carried out, the level and types of waste can be clearly identified and steps taken to systematically eliminate.

1.3 SELECTED LEAN TOOLS

There are several Lean tools and techniques that can be used to help establish efficient processes and practices and/or to improve performance in the construction industry. A comprehensive list of 29 tools/activities is included in Table 9.1.

This guide focuses on a selection of Lean tools that will help in the initial stages of improving project delivery performance and cover activities in the pre-construction and construction phases of a project. These individual tools or families of tools are described with an outline of when and how to use them.

Any selection is subject to debate. Some Lean experts may not agree with this selection. However, in creating this shortlist, the aim is to:

- ▶ illustrate a selection of tools that, between them, have applicability across different project phases from initial feasibility to handover and maintenance

- ▶ use the authors' experience, together with the advice of the project steering group, in describing tools known to work in construction.

The following sections should help to:

- ▶ understand the background and meaning of various Lean terms and tools that are widely used and talked about
- ▶ for newcomers to Lean, focus initially on a selection of Lean tools, which can be added to as experience grows
- ▶ gain an overview of how each tool can be applied.

Chapters 2 to 8 of the guide cover the following areas:

- ▶ **Chapter 2** Delivering to vision, objectives and strategy
- ▶ **Chapter 3** Lean collaborative planning and project management
- ▶ **Chapter 4** Structured problem-solving
- ▶ **Chapter 5** Workplace organisation
- ▶ **Chapter 6** Visual management
- ▶ **Chapter 7** Process improvement
- ▶ **Chapter 8** Operations improvement.

The tools vary in breadth and applicability. Readers interested in obtaining a broad overview might wish to read the chapters in order, while those focused on process or operations improvement will find Chapters 7 and 8 of greatest initial interest.

When reading or using this guide, the aim is that it will help to approach and apply Lean as a step towards achieving the benefits it has to offer.

Table 1.1 lists the tools and their applicability across project phases.

Just do it!

You may feel in your current role that you have little or no influence or authority to use one or more of these Lean tools to make an improvement. The important thing is to do something. Ideally the Lean tools would be applied as part of a concerted effort and improvement strategy for your business and/or a project. Failing that, by applying an appropriate tool to activities that are within your field of control, you will be amazed at the benefits you and your team can realise. Note that when making improvements to processes and practices within your field of control, you must consider the effect on preceding and later processes. Here we mean that improvement for a project should be made with the overall project improvement objective or 'Hoshin' (see Chapter 2) in mind.

Table 1.1 Lean tools and techniques covered in this guide

Lean tool/activity	Project phase				
	Feasibility	Design	Mobilisation	Construction (production/installation)	Handover and maintenance
Delivering against agreed vision, objectives and strategy for project delivery (Hoshin Kanri)	**	**	**	**	
Lean collaborative planning and project management	*	**	**	**	*
Structured problem solving	*	**	**	**	**
5S workplace organisation		*	**	**	
Visual management	*	**	**	**	
Process management					
◆ process of activity flow map	*	**	**	*	*
◆ swim lane map	*	**	**	*	*
◆ SIPOC map	*	**	**	*	*
◆ value stream mapping and analysis		**	**	**	
Operations improvement					
◆ eliminating factors that prevent the effective and efficient completion of work	*	**	**	**	*
◆ performance monitoring, analysis and improvement	*	**	**	**	*
◆ day in the life of (DILo)		*	*	**	*
◆ first run study/direct observation of work			*	**	*
◆ standard operations		*	*	**	*

Key

** = Primary relevance

* = Secondary relevance

2

Delivering against agreed vision, objectives and strategy for Lean project delivery (Hoshin Kanri)

2.1 WHAT IS IT?

Experience shows that projects seldom fully align the overall objectives of the various contributors into a common, cohesive and deployable strategy. Without this clarity of purpose with clear, agreed targets to challenge and guide the project not just to deliver on time and to budget, but also to exceed to a higher set of standards, many projects fail to hit their basic requirements. From a Lean point of view this is exactly opposite to the requirements for high-performing teams of people focused on common goals and mutual benefit.

Hoshin is a Japanese term that translates as 'shining needle', effectively meaning a directional pointer as in a compass. Kanri translates as 'management'. The term Hoshin Kanri refers to a process for setting an agreed strategic purpose and direction for an organisation, business and/or project, to which all elements and parties align and deliver. For a construction project this means defining what success looks like in terms of clear objectives, such as 'reduce programme time by 20 per cent to drive the project forward'. All parties should agree and then set about how to ensure the defined objectives will be delivered. This establishes the basis for an agreed project delivery process, which includes the appropriate application of Lean thinking, methods and tools.

2.2 WHEN AND WHERE TO USE HOSHIN KANRI

Application of Hoshin Kanri to a construction project will depend on the size and complexity of the project and should reflect the level of investment in processes for project planning, management and control. Where appropriate, one or more strategic alignment workshops should be held to bring together key project contributors to collaboratively shape a common vision, strategy, goals and objectives. This process should begin when the project starts to define the overall project objectives and involve individuals responsible for project delivery from the customer, client, designer and contractor, project manager, quantity surveyor, programmer, cost consultant etc.

2.3 APPROACH

The Hoshin Kanri process typically follows the following steps:

- 1 Define and agree the vision and objectives for the project – one or more strategic alignment workshops involving the key decision makers from each interacting party. A single page plan

(see Figure 2.1) can be used to summarise the agreed project (or 'vital few') objectives, the projects or actions that will be enacted to deliver the objectives, the owners, target dates, how success will be measured and the targets. This sheet can also be used to monitor status of actions and achievement of the objectives.

- 2 Agree processes for measuring, displaying, reporting and governing – this should also be an output from the strategic alignment workshop. Clear roles and responsibilities for project delivery and management should also be defined.
- 3 Communicate the vision, objectives and process to all project parties and participants – once set, the vision, objectives and strategy are cascaded down through the project organisation until they become part of the induction process of all project participants. Further sessions should be used at each phase of the project to ensure continued strategy alignment and effective deployment by the operating team for that phase.
- 4 Implement and operate – closely monitor performance and achievement using the agreed set of measures. This process extends from the typical monthly review of project status into weekly production review and planning meetings and daily work activity planning and control.

2.4 BENEFITS TO CONSTRUCTION

A well thought-out and deployed strategy results in the alignment of purpose in every aspect of the project, leading to:

- ▶ improved project delivery performance in terms of value, quality, programme and cost
- ▶ alignment of all parties to deliver against an agreed set of project objectives
- ▶ clarity of communication
- ▶ a common guide for decision making, target-setting, reviewing and improving
- ▶ the basis to which all aspects of project delivery should seek to relentlessly deliver
- ▶ the foundation for collaborative working

Further benefits include:

- ▶ all parties are focused and aligned to achieve the agreed objectives, working together in a non-adversarial way
- ▶ the teams are pushing further than their first improvement targets, positively challenging how far they can go
- ▶ the teams are happily, proudly and visibly reporting on their success
- ▶ the teams are willing to take coaching and review their work processes
- ▶ the teams challenge management when standards are slipping.

Case study 2.1 Using Hoshin Kanri to improve project delivery performance

A UK water company had several projects to rebuild and needed to add extra plant to several sewage treatment plants. It was important to create clear direction and communication of that direction throughout all of the projects. These were complex operations that had many elements, were on multiple and currently operating sites and (although similar in many ways) had significantly different physical plants.

The common requirement for all the projects was to deliver improved gas production on time for all plants. To do this, a common measure was needed to challenge the project teams to focus on delivery for all project activities. The simple targets of a 20 per cent reduction in delivery time and 'right first time' quality were chosen. These two targets captured the strategic requirements for the project and were communicated to every aspect of the project work.

Actions identified related to:

Design delivery	Design flow	Design plan	Visual management
Collaborative planning	Weekly planning	Daily start of shift planning	First run studies
Standard operating procedures	Structured problem solving	Escalation process for resolving issues	

3

Lean collaborative planning and project management

3.1 WHAT IS IT?

There is great synergy between Lean and collaborative working. Team working is a fundamental feature of a Lean culture focused on continuous improvement. For a construction project, collaborative planning and project management is an essential process that supports a Lean approach and embodies key principles of Lean.

Collaborative planning and project management brings together representatives from all organisations involved in a construction project. The aim is to jointly develop an agreed target programme that all project activities, design, procurement, construction and support will be aligned and managed to.

This technique consists of several main steps (see Figure 3.1).

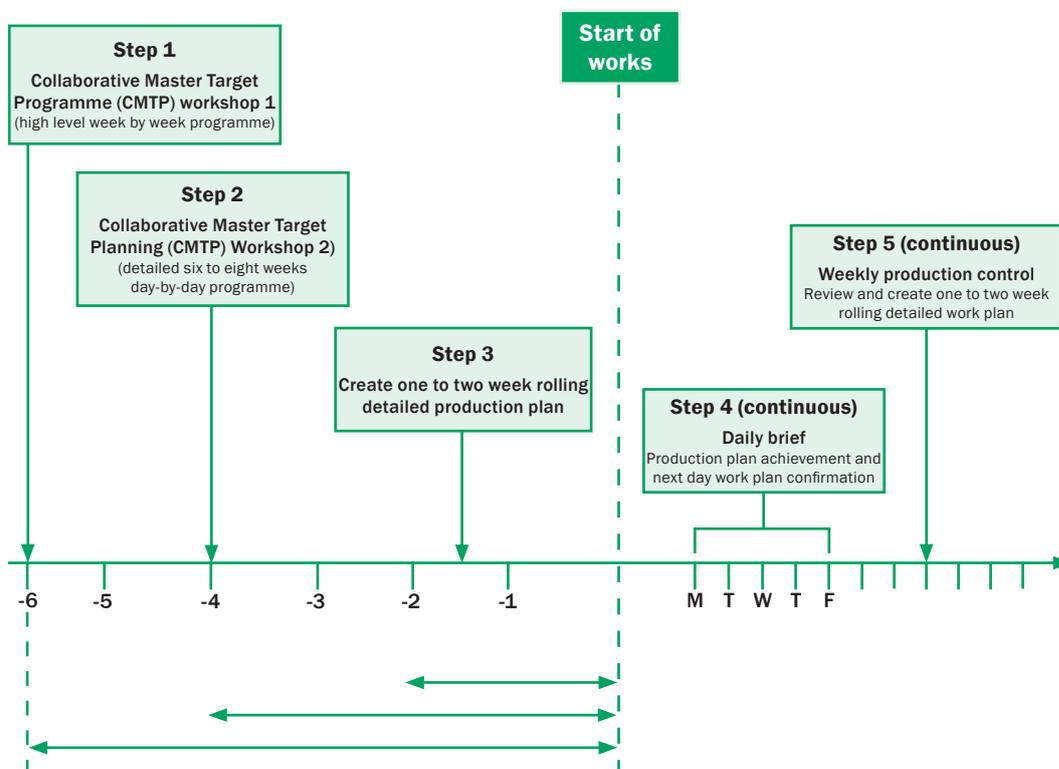


Figure 3.1 The key steps of Lean collaborative programming and project management

3.2 WHEN AND WHERE TO USE COLLABORATIVE MASTER PROGRAMMING

To optimise the benefits achievable through the Lean collaborative programming technique, ideally the process should be applied early in the project life cycle. The purpose of master programming is to provide a project team the opportunity to create a common, aligned and collaborative view of a project programme. Seldom do people working on project gain a comprehensive, accurate and aligned view of the programme without such a process. Engaging in this process facilitates:

- ▶ clarity of design delivery based directly on construction requirements
- ▶ precise design requirements of procurement and construction design
- ▶ detailed alignment and efficiency for the sequencing of subcontractor starts and interfaces
- ▶ the identification of logistical requirements and conflicts
- ▶ a view for uncovering opportunities for programme improvement
- ▶ a structure for the analysis of constraints and threats to the programme and project
- ▶ procurement can be synchronised to programme requirements with more certainty
- ▶ the contractor and subcontractors have a better basis to plan and organise resources.

The process can also be used at any point in the life cycle of a project and has proven useful as a tool to help recover projects that may overrun. The full technique comprises five steps.

- 1 High-level collaborative master target programme
- 2 Detailed level collaborative master target programme
- 3 Short-term detailed production plan
- 4 Daily brief
- 5 Weekly production control

The level of formality used for each step and indeed the number of steps applied can be varied depending on the size and level of complexity of the project that it is applied to. For example, for a high-value and/or highly complex project, it is recommended that all the steps are formally applied, using a rigorous structured process. For a low-value project that is much simpler and probably of short duration, a less formalised application of the technique could suffice (eg Steps 1 and 2 or Steps 2 and 3 could be done together).

Case study 3.1 Programme recovery

Collaborative planning was used to help recover a lengthy project overrun situation on a £1.4m leisure centre refurbishment and new build. The programme was delayed 22 weeks due to a steel shortage problem. With the steel delivery issue sorted, collaborative planning involving the client, designers, contractor and subcontractors was used to challenge the current programme and to identify ways to expedite construction activities more efficiently. This included better phasing of works, enabling improved flow of trade activities and improved productivity.

Result: 14 weeks out of the 22 weeks forecast overrun were saved.

3.3 APPROACH

Steps 1 and 2 are used to develop an agreed target programme. Steps 3 to 5 relate to the short-term planning and control activities. The process uses the agreed collaborative master target programme (CMTP) as the basis for weekly and daily planning and control of project production activities. The short-term planning process (similar to that referred to as Last Planner™), improves programme predictability by seeking all project partners' commitment to complete

activities as scheduled. Table 3.1 shows the typical participants and their involvement in this process, and should include anyone who can influence or affect the plan.

Table 3.1 *The typical participants for each step of the Lean collaborative planning and project management process*

Step	Client	Designer	Contractor	Subcontractor
1	Project manager (PM), operations and maintenance personnel	Architect/designer	Contracts manager (CM), project manager (PM), buyer, planner, quantity surveyor (QS)	Project manager (PM), planner + possible design involvement
2	PM, operations and maintenance	Architect/designer	CM, PM, buyer, planner, QS	PM, planner, works supervisor
3	PM – occasionally	Architect/designer (to plan their work)	PM, planner, site supervisor(s)	PM, works supervisor
4			PM, site supervisor(s)	Works supervisor
5			PM, planner, site supervisor(s)	Works supervisor

Each step of the technique is described as follows.

STEP 1: High-level CMTP

The first collaborative planning workshop should be held as early as possible at the start of a project. The initial workshop aims to develop a high-level programme to define an agreed sequence of work activities, target durations and how different trades should work together in terms of sequential or parallel working. Also, it is important to identify dates when designs need to be provided in support of the agreed CMTP. The main aim is to improve programme predictability but should also include programme challenge to identify opportunities for reducing time and/or cost. The process creates an agreed master target programme by applying the principles of lead time reduction, sequence, small batch production, pace of production and flow. Other principles such as buffer programming and theory of constraints (Chapter 9) are also used to help identify critical and pace-maker activities that help define the pace of production to be achieved in the programme.

The aim is to get a ‘tight’ but realistic and achievable programme. Float or buffer time is generally added to the end of the programme, so that if any events do delay construction activities, the planned activities are shifted from left to right on the programme, and the level of remaining float used as a measure of programme status. Float is only added within the programme where it is considered necessary (eg associated with critical or constraining activities – those activities that pose complex or difficult points of construction).

The result of this step is an agreed CMTP, which sets the timeframe that all aspects of project work should align to. Also, as all organisations involved in the project will be represented in the workshop, it is normal to find that many issues and/or queries raised can be dealt with immediately. For those issues that cannot be resolved, a ‘plan-to-protect’ is developed to ensure effective and timely resolution.

Plan-to-protect is used to support the collaborative planning and project management process. It aims to prompt a project team to proactively identify and deal with any known or likely issues that would have a detrimental effect on the efficient and timely delivery of the agreed programme. It is similar to risk management in that issues are logged and actions taken to either design out each issue or to identify contingency actions that can be carried out quickly if needed. Figure 3.3 shows the layout and content of a simplified plan-to-protect sheet.

Ideally, the workshop output, is taken by the project manager and used as the basis for weekly short term planning, review and status monitoring. The collaborative planning sheets can be taken by the planner for transfers into the programming software used for the project. This enables programme logic, resource loading and critical path analysis (if used) to be carried out. Sometimes, minor adjustments to the collaborative programme then may result.

On each Post-It note, describe the nature of the issue and identify the potential effect of the problem.

Ask members of the team to add their initials in case further details are required.



Figure 3.2 Showing the highly practical, interactive, hands-on and collaborative nature followed when developing the collaborative master target programme

Note that sticky Post-It notes are used to chart work activities on large planning sheets, each sheet showing five working days plus weekends. Participants are encouraged to challenge any initial views relating to programme for their works, use 'real' activity durations, identify where and when simultaneous work activity can be carried out and where improvements in programme can be made.

Issue	Action	Owner
<p>Issue Nam, quam re pedis, consequs porshendae occus assi debet latin</p> <p>Impact taquias aritratatis esse vendae dolupta tiatis et ommodituis</p> <p>RO'C</p>	<p>Meeting to discuss the window reveal issue and then create design details</p>	<p>J Bloggs</p>
<p>Issue Iea si cum excoperis dolupti sersper itauctorati</p> <p>Impact Um dolorenarrio con porio eictem con porio eicts</p> <p>RO'C</p>		
<p>Issue Design detail for window reveal needs to be finalised</p> <p>Impact Potential to delay start of the window package</p> <p>RO'C</p>		

Issue
Design detail for window reveal needs to be finalised

Impact
Potential to delay start of the window package

RO'C

On each Post-it, describe the nature of the issue and identify the potential impact of the problem.

Ask members of the team to add their initials, in case further details are required.

Figure 3.3 An example of a simplified plan-to-protect sheet

STEP 2: Detailed level CMTP

The next workshop uses the high level CMTP developed in step 1 to develop a detailed daily programme typically for the first six to eight weeks. Sometimes it is useful to align the detailed planning period to main phases in a project (eg ground works to water tight or second fix finishes to complete). Often a balance needs to be struck between the period duration to be programmed and the level of detailed day-by-day work activity planning that can be realistically programmed. This balance will depend on factors such as the complexity of works, the number of trades working and the resource logistics situation associated with the period of works to be planned. The length of period to be programmed should be sufficient to enable 'look ahead' planning. The resulting programme should be considered as a rolling programme, with step 2 being repeated at four to six week intervals to develop the detailed day-by-day programme for the next six to ten week phase of work.



Figure 3.4 Activity planning

During this workshop, all interfaces between different areas of works and trades should be considered. The attendees should be challenged to apply 'real' activity durations and to identify any opportunities to improve. The rate of production, how resources will be organised and deployed and the required materials logistics to support the programme should be considered. Having run this process on numerous projects, the authors have found that opportunities to improve methods, durations and sequence often are realised as the designer, contractor and subcontractors work closely together. Once created, the programme provides a detailed 'look ahead' programme. A check is carried out to ensure everything necessary to enable planned works to be carried out will be in place as and when required (ie plant, materials, labour, information, permits). This is also known as 'make-ready needs'. Status of design completeness to the agreed programme should also be covered. If necessary, actions are agreed to resolve any issues. The plan-to-protect should be updated and a detailed logistics plan created.

Also, this detailed planning/scheduling process can be applied to develop a design delivery schedule, which is aligned to the agreed detailed CMTP. This provides the basis for the designer to plan and effectively deploy design resource to ensure timely provision of design.

3.3.1 Tips when applying CMTP

- ▶ use an independent facilitator skilled in running CMTP workshops. They will be able to take an objective view of the programme and related project situation
- ▶ use a work space/room big enough to clearly lay out the sheets that the collaborative plan will be formed on, and also to display associated information, including detailed design drawings and site layout diagrams
- ▶ ensure that the appropriate representatives from all interacting parties attend the workshop. Decisions on the programme need to be made and the planned work activities, including durations, must be realistic and adhered to.

It is often useful to challenge the attendees to develop a collaborative programme that has a shorter duration than that defined within the contract programme. Often, a 20 per cent reduction in duration is sought. This immediately encourages each party to consider what can really be achieved and then to allocate improved activity durations. It also highlights the necessity of ensuring that any issues that might affect the accurate delivery of the programme need to be proactively resolved and a rapid problem resolution process put in place to quickly deal with any issues as they arise.

STEP 3: create short-term detailed production plan

One to two weeks before start on site (or ahead of the project phase being programmed), a brief (eg one to two hour) workshop should be held to confirm the work activities planned for the first one to two weeks of the project. This should form the detailed production plan and all things (ie labour, materials, plant, information, permits) necessary to carry out the works should be confirmed as being ready as and when needed. This workshop should be attended by the people who will be responsible for doing and organising the works (eg contractor project manager and trade supervisors), as these are the people who will make it happen.

STEP 4: daily brief

Once the weekly (or two-weekly) production plan is defined and the project is underway, daily briefing sessions should be used on complex and fast-moving projects to track daily progress against planned progress and make any adjustments in response to any gains or losses to programme. Also, any issues that have affected the accurate and timely completion of any work activity should be logged along with the associated time lost quantified. This will enable later analysis and problem solving (see Chapter 4). This session should be run by the contractor project/site manager or (on large project) the area supervisor, together with trade supervisors.

STEP 5: weekly production control

A weekly meeting is held by the contractor project/site manager with the trade supervisors and work planners (if appropriate) to review the previous week's works completed versus planned works. Often a percentage planned complete (PPC) measure is used to assess the level of achievement. A word of warning: it is important to quantify and measure the actual amount of work completed versus that planned. The status of programme in terms of being ahead, on-time or behind programme should be reported and tracked. Another measure that can be used is the level or percentage of known float remaining in the programme. During the meeting, the production plan for the coming week is defined, make-ready needs are confirmed and actions to address any issues added to the plan-to-protect.

Steps 4 and 5 ensure that all parties remain focused on applying a collective approach to deliver the agreed CMTP.

3.3.2 Tips when applying short-term collaborative planning and project management

- ▶ attendees at the weekly and daily planning sessions should be those people responsible for planning and supervising the works, ie those people best placed to provide timings and commitment to the required resources
- ▶ ensure the short-term planning and control process is rigorously applied and adhered to with all required representatives in attendance. Missing a daily or weekly session will start to erode the importance and usefulness of the process
- ▶ it is important to ensure that collaborative plans created for different aspects or work streams on a project are effectively linked back to an agreed overall programme (ie the

agreed target master programme). This will help ensure that the effect of any issues and/or changes necessary in any project area is understood. Any change in important project milestones and/or priorities can then be agreed so that all areas of the project can work to agreed whole project objectives

- ▶ issues affecting the accurate and timely achievement of planned works should be dealt with outside of the weekly planning and daily review and plan adjustment sessions. These sessions should be efficiently run and focused on the plan
- ▶ work with the trade supervisors/leading hands to actively consider how they will best carry out their planned works for the next period (ie next day and next week).

3.4 BENEFITS TO CONSTRUCTION

The collaborative master planning and short-term planning and management activities ensure effective delivery of the agreed programme and have the following benefits:

- ▶ the collective knowledge and experience of the whole team is used to develop and deliver against a collectively agreed target programme
- ▶ predictability of programme delivery and cost improves
- ▶ programme times can be reduced by up to 30 per cent
- ▶ any gains in short-term programme(s) can be capitalised into the main CMTP programme helping to improve certainty of delivery
- ▶ creates continued focus and momentum to deliver agreed project delivery goals
- ▶ supports the 'one-team' collaborative project culture
- ▶ ensures known and potential issues are effectively dealt with so that planned activities can be completed.

Case study 3.2 New build of a large superstore for a well-known retailer

A contractor had previously completed 40 projects for a retail client, the projects being a mixture of refurbishment of existing stores and construction of new stores, including several super- or large-sized retail outlets. The contractor had a day-by-day programme for construction of a new superstore. However, although this programme was very detailed, it was based on the way of doing work and achievements in build completion from previous stores.

The contractor 'tried' a collaborative planning workshop to see if this technique could help them ensure programme completion. At the time of the workshop the new superstore was already in construction up to roof stage. The workshop concentrated on the finishing stage and was able to create an improved programme delivering the stores six weeks earlier than previously planned.

Structured problem solving

4.1 WHAT IS IT?

Structured problem solving is a team-based approach for continually identifying and then resolving issues and/or events that have a detrimental effect on the effective completion of a work activity. Typically a problem is related to an issue in safety, quality, predictability, productivity and/or cost. The aim is to identify the real origin or root cause of a problem and resolve the problem at source instead of continually dealing with the symptoms of a problem. Problem solving can also be used to help define the best way to carry out a new task or activity, since potential modes of failure can be identified and action taken to design these out. This approach is similar to that embodied with failure mode effect analysis (FMEA), a technique not covered in this guide.

4.2 WHEN AND WHERE TO USE STRUCTURED PROBLEM SOLVING

Structured problem solving can be used at any stage of a project or process, in response to one or all of the following:

- ▶ the identification of a known or potential problem
- ▶ where there has been a drop in expected performance
- ▶ where data analysis has identified a recurring issue that detracts from available productive time or production efficiency (things or events that introduce delays or disruptions, quality defects, excessive snags etc).

4.3 APPROACH

The typical steps associated with structured problem solving are described in Table 4.1.

Table 4.1 Structured problem solving

Problem	Identify the problem. Seek to quantify and capture the general nature of the problem. Can the problem be quickly resolved? If not, move to next step.
Containment	Aim to protect the customer (in this case the project). Can the process/activity that the problem relates to be contained with a short-term fix to enable the process/activity to continue?
Team	Assemble a multi-discipline team appropriate to the type of problem and process (or activity). The team should include people working in the process and individuals with relevant technical expertise as necessary.
Understand	Investigate the problem situation by visiting the process, speaking to people involved and analysing data. Fishbone analysis (see Section 4.3.1) is often used.
Identify root cause(s)	The team use 'five why analysis' (see Section 4.3.1) to identify the real root cause of the problem.
Develop solution	Develop the solution to resolve the root cause of the problem. Involve the people working in the process to develop improvement ideas and agree that would be the 'best' solution.
Implement solution	Use plan-do-check-act (see Section 4.3.1) to implement the solution to the root cause.
Validate	Monitor the process to ensure that the solution has worked.
Prevent recurrence	Update any related process documentation (eg method statement or standard operation procedure) to reflect the change in the process. Train all relevant people in the new/revised process.

4.3.1 Associated techniques

There are many techniques that can be used to support structured problem solving including:

- ▶ A3 problem solving
- ▶ Fishbone analysis
- ▶ 5-whys analysis
- ▶ plan-do-check-act.

An A3 problem-solving sheet provides a standard template that a team can use to ensure a structured approach is applied when resolving the root cause of a problem and proposing remedial or counter-measures. Figure 4.1 shows an example related to resolving an important quality issue on a property refurbishment project.

Fishbone analysis (also known as 'cause and effect' or Ishikawa) is a visual or diagrammatic brainstorming process to identify factors most likely to contribute to the problem. A standard template that resembles the bone structure of a fish is typically used (see Figure 4.2). A completed Fishbone diagram is included in Figure 4.1.

The 'problem' statement is written at the head of the fish. The team then identifies potential contributory factors to the problem under the headings of material, person, machine, method and environment. Once all potential contributory factors have been identified, the team then agrees the factor(s) that would be the most likely main contributor(s) to the problem being investigated. Often data is used to help quantify the impact or level of contribution a particular factor has on the problem and this helps direct the decision. It is this factor that then becomes the focus of a 'five why analysis'.

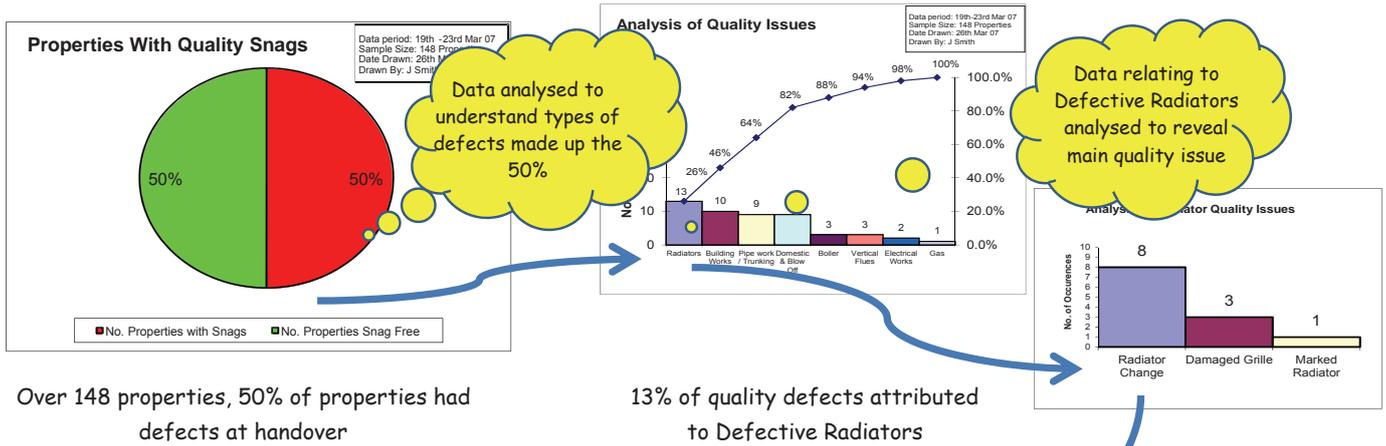
Five why analysis is a systematic questioning process used to identify the root cause of a problem (see Figure 4.3).

THE PROBLEM:

Excessive level of quality defects at handover

INFORMATION RELATING TO THE ISSUE		CONTAIN	
Date Raised: 20th March '07	Where: Decent Homes Project XYZ	How: Toolbox talk to all trades plus closer supervision and review at property sign-off	Who: Supervisors
Originator: F Smith	Work Stream: All		Where: All work streams
			When: Immediate

UNDERSTAND THE ISSUE



IDENTIFY THE ROOT CAUSE

Fishbone Analysis

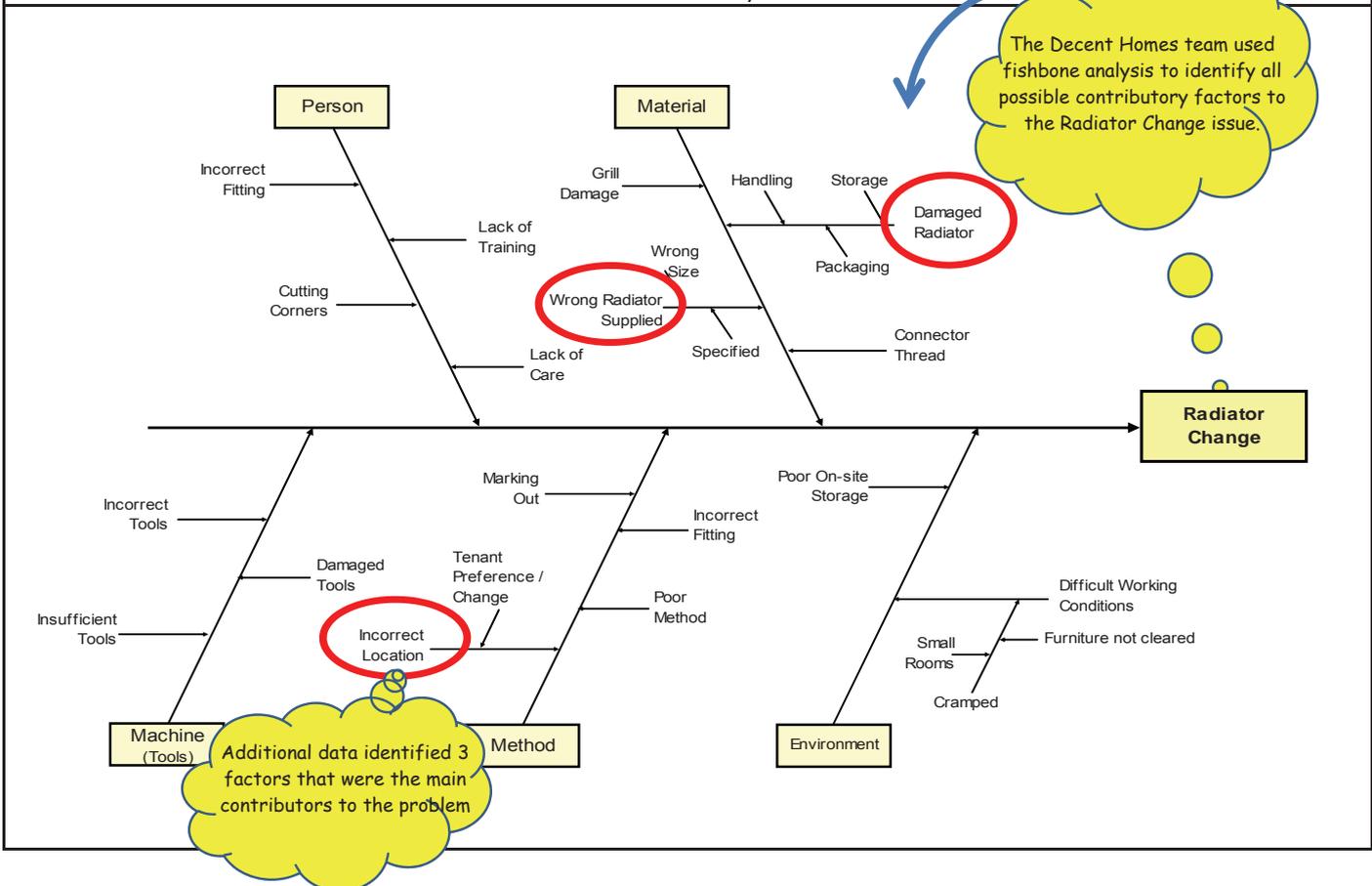


Figure 4.1 Example A3 problem-solving sheet

A3 PROBLEM RESOLUTION SHEET

IDENTIFY THE ROOT CAUSE

5 Why Analysis

	Wrong Radiator Supplied	Damaged Radiator	Incorrect Location			
WHY 1	Incorrect specification	Poor storage practices & handling	Variable method of specifying position of radiator in a room			
WHY 2	Unclear and variable approach between the Surveyors	Materials, parts and componentry stored randomly and poorly, often on top of one another resulting in double handling, scuffing and damage	Method not defined plus some Surveyors &/or Plumbers changed optimum position in response to Tenant request			
WHY 3	Unclear method + different assumptions used when calculating size of radiator required	Too much stock stored and poor organisation of central stores	Method never formally defined nor enforced			
WHY 4	Method never formally defined	Poor materials planning and management processes	Not considered to be an issue			
WHY 5		Main focus and effort directed towards works delivery with limited visibility or understanding of stores set-up and operation	Management never 'sighted' as the issue due to no / limited data			
ROOT CAUSE	Client team relied on Surveyor experience and did not see the need to define method	Not considered an important focus and stuck with what was common current practices				
COUNTER MEASURE	Work with Surveyors, Decent Homes work stream supervisors and plumbers to define an agreed method. Develop standard operating procedure. Train all relevant people.	Carry-out a 5S Workplace Organisation activity to improve the set-up, organisation, operation and management of the central stores. Rationalise stored stock. Develop standard operating procedure to support. Train all people in new methods.		Define and standardise method (link to root cause countermeasure as for 'Wrong Radiator Supplied'), train all relevant people. Contractor and trade supervision to ensure standard approach to radiator position is adhered to.		
	Owner	Target Date	Owner	Target Date	Owner	Target Date
	F Smith	9th April '07	H Jaycock	16th April '07		
VERIFY RESOLUTION / IMPROVEMENT ACTION	PDCA applied Yes	Design revision required? No	SOP updated / created? Yes			
	Team brief? Yes	Benefits realised? Yes - Issue resolved	Issue resolution documented? Yes and logged as part of learning portal			
	Improvement Sign-off 		Other areas where the Improvement can be applied Other Decent Homes programmes			

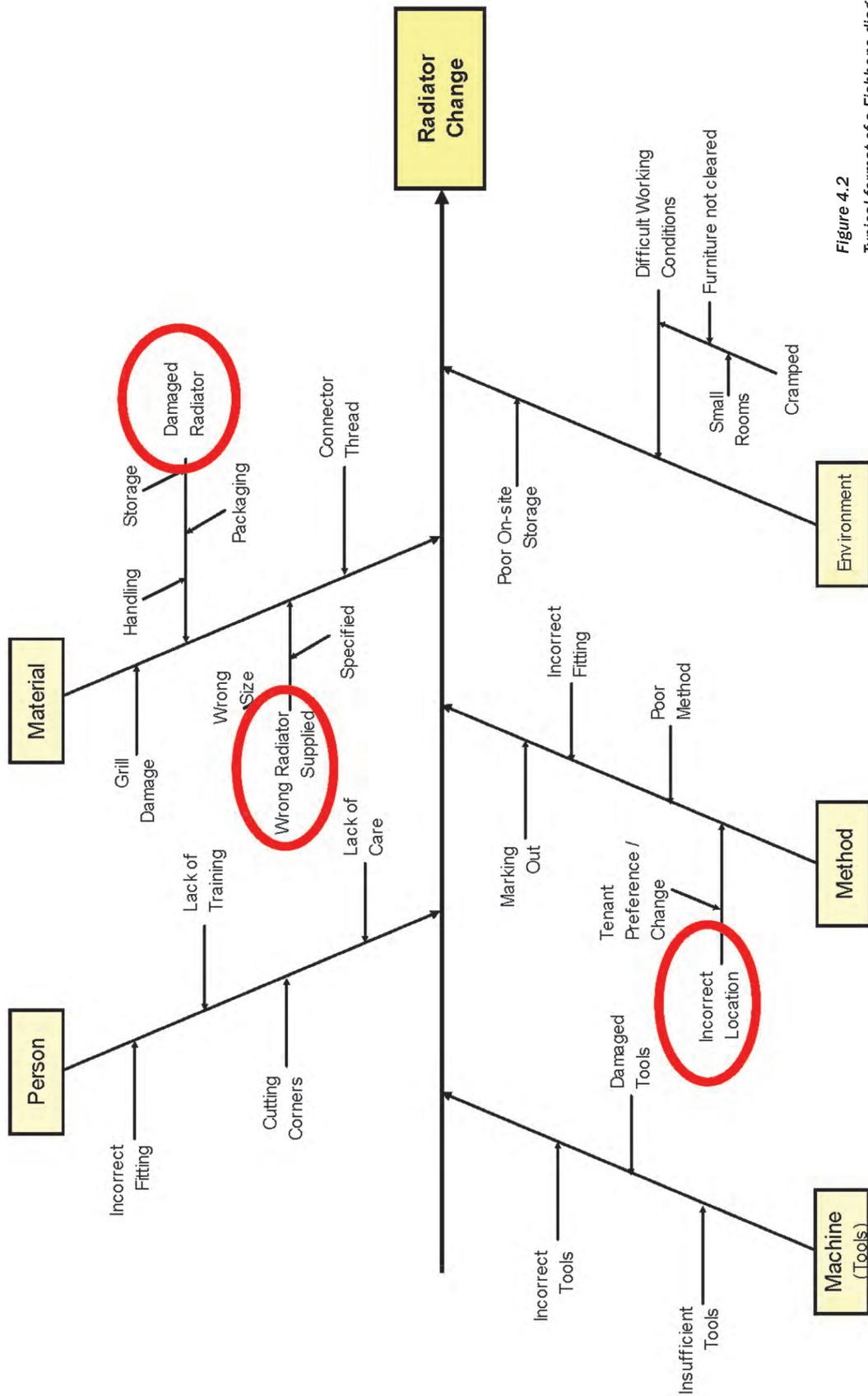
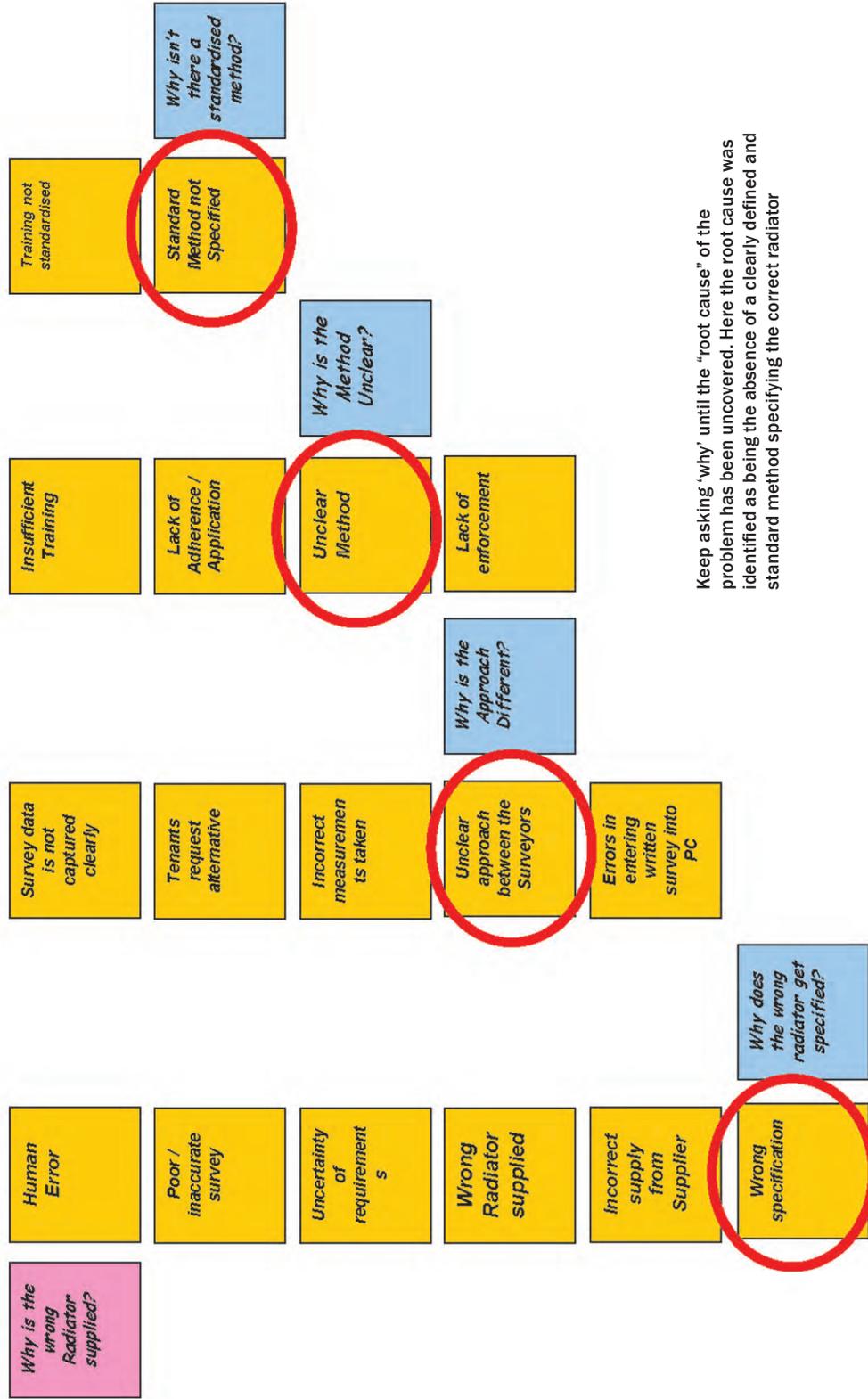


Figure 4.2
Typical format of a Fishbone diagram

The most likely factor(s) contributing to the problem becomes the focus of the five whys activity. In this example 'wrong radiator supplied' was deemed from the fishbone analysis (see Figure 4.2) to be a key factor contributing to the problem 'radiator change'.



Keep asking 'why' until the "root cause" of the problem has been uncovered. Here the root cause was identified as being the absence of a clearly defined and standard method specifying the correct radiator

Figure 4.3
Example five why analysis

Plan–do–check–act (PDCA), also known as the ‘improvement cycle’, is a structured four-step approach to process improvement (see Figure 4.4). Typically drawn as a circle, PDCA has no end and should be repeated again and again. It supports small step continuous improvement and, when applied well, will help ensure sustainable improvement.

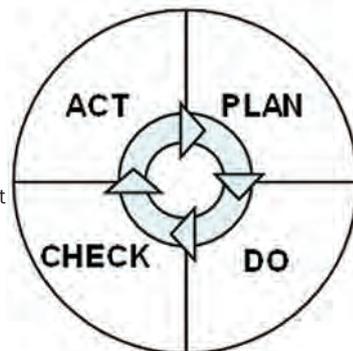
4.3.2 Tips when applying structured problem solving

- ▶ the problem-solving team should be no larger than six to eight people
- ▶ ensure a good understanding of the problem, visit the process, talk to the people involved
- ▶ use the PDCA cycle to ensure successful implementation of any resolution.

4.4 BENEFITS TO CONSTRUCTION

- ▶ improved predictability
- ▶ reduced variability
- ▶ less process waste, which should result in less time and/or resources
- ▶ improved performance in safety, quality, delivery and cost
- ▶ more stable project delivery process
- ▶ improved morale
- ▶ customer and client satisfaction.

- ▶ analyse any differences and identify their root cause
- ▶ make changes as needed – enter into the PDCA cycle again
- ▶ if the change/improvement was successful, look to standardise as the new best method/practice.
- ▶ review the change/improvement
 - ▶ outcomes as expected?
 - ▶ any health, safety or welfare concerns?
 - ▶ quality to the expected standard?
 - ▶ efficient and productive methods?
- ▶ any opportunities for further improvement
- ▶ review with and communicate to all relevant stakeholders.



- ▶ recognise an opportunity
 - ▶ diagnosis
 - ▶ understand the nature of the opportunity
 - ▶ measure, assess and set desired outcomes
- ▶ plan the change/improvement
 - ▶ why, what, who, where, when, how
 - ▶ risk assessment
- ▶ review with and communicate to all relevant stakeholders.
- ▶ implement the ‘plan’ (ie change or improvement)
- ▶ ‘hand-hold’ the change/improvement
- ▶ work with the process stakeholders
- ▶ refine as necessary
- ▶ collect data for review in the ‘check’ and ‘act’ phases of the cycle.

Figure 4.4 The plan–do–check–act (PDCA) improvement cycle

5S workplace organisation

5.1 WHAT IS IT?

5S is a fundamental building block of Lean and continuous improvement. 5S provides a structured method for achieving, maintaining and improving the standard set-up, organisation and layout of a work area so as to ensure safe and efficient operations, with minimal waste.

5.2 WHEN AND WHERE TO USE 5S WORKPLACE ORGANISATION

5S applies to any work area (ie site areas of work, materials storage areas, offices). It can also be applied to improve the set-up and organisation of a desk or office. A 5S improvement activity should be carried out by the people who work within the area/process, so that ownership of the 5S standard, its maintenance and improvement is achieved.

5.3 APPROACH

The 5S approach consists of five simple steps (see Table 5.1 and Figure 5.1).

Table 5.1 The 5S approach

5S Step	What is it?	Why do it?
1 Sort	Separate the items that are essential to the process or activity from the non-essential. Remove the non-essential.	Remove clutter from the workplace and ensure time is not wasted looking for an item.
2 Set (or straighten)	'A place for everything and everything in its place'. Define the location for each essential item so that it supports safe and efficient working. Set the layout for a work area including locations for materials, plant and equipment.	Safer working environment. Everything is easy to find and to-hand. Making it easy to spot things that are out-of-standard and/or that might affect the process (eg low stock level).
3 Shine	Keep the work area clean and tidy. Ensure tools and equipment are clean and in good working order.	So that the set 5S standard for the work area, tools, materials and equipment is maintained.
4 Standardise	Set the standard and make it easy to see and maintain.	To ensure safe and productive working is repeatedly achieved.
5 Sustain	Sustain through training, audit and consistent application.	So it becomes part of the everyday way of doing work.



Figure 5.1 The 5S approach

5S should become a core principle for the way that workplaces are set up, operated and organised. It directly supports safe working practices and represents the standard that a construction site should be operated at and the way work is carried out. To understand the value of a disciplined 5S construction site, consider the hundreds of thousands of movements that take place on a site. Think what it would mean to have them all to be ‘right first time’:

- ▶ the materials that are needed were always there when needed
- ▶ always the right amount of fittings
- ▶ deliveries did not go to the wrong part of the site
- ▶ stocks of materials are minimised and well managed because the status of materials as they are used is clearly visible, ie those people responsible for calling off materials can do so by simple visual survey.

5S is a tool and approach that is carried out at the micro level of operations and is applied everywhere continuously. For example, Figures 5.2 to 5.4 are from a project at Stansted Airport that show three areas of 5S organisation.



Figure 5.2
Specific and well-ordered material set-down areas enable easy management of inventory

Each has the benefit of clarity for finding what is needed, managing replenishment of supplies and creating a safe environment for materials and for the movement of vehicles and people.

5.2.1 Tips when applying 5S

- ▶ always involve the people who work in the area or process that is the focus for the 5S activity. This will help create acceptance and ownership of the 5S standard, and later maintenance and improvement of the standard
- ▶ use plan–do–check–act (see Section 4.3.1) to help structure the 5S activity



Figure 5.3
A well-ordered storage of fixings that is attached onto the work scaffolding will minimise searching for materials and unnecessary bending, twisting or walking for materials



Figure 5.4
5S organisation supports visual management – clear, easy to read signage for efficient site vehicle movement

- ▶ carry out a risk assessment to ensure the 5S activity is carried out safely
- ▶ clearly instruct all participants to ensure safe working practices at all times.

5.4 BENEFITS TO CONSTRUCTION

- ▶ creates a safer working environment – fewer trip hazards
- ▶ supports efficient working – wasteful, non-productive time is minimised as materials, tools, equipment and plant are organised and to hand
- ▶ sets the standard of working for the construction site
- ▶ makes things easier to see – can spot potential problems and inefficiencies
- ▶ supports visual management
- ▶ promotes a good working environment resulting in improved morale and image.

Case study 5.1 5S and visual management

As part of a programme improvement activity for a social housing regeneration project, a 5S workplace organisation activity was used to improve the organisation and control of stocked materials. Storage areas were established for each work stream and laid out into five specific storage bays, one for each working day, Monday to Friday (see Figure 5.5). Stored materials such as kitchen units, sinks, plumbing kits etc that were to be installed in specific properties were positioned in the appropriate bay according to the weekly refurbishment programme. A visual board that mirrored the layout of the materials store was designed and used to help plan and control stock. The status of production was now easy to see either by visiting the store and/or by looking at the visual board. If a worker was in on a Wednesday and Tuesday's stock was still there, immediately they will see that there was a problem in the production cycle. The 5S and visual management improvements helped halve the amount of stock held, reduced the level of cash tied up in inventory and released storage space, meaning that a second facility did not have to be procured and saving £30k+ per annum. This activity supported the reduction in property completion time from 22 days to 15

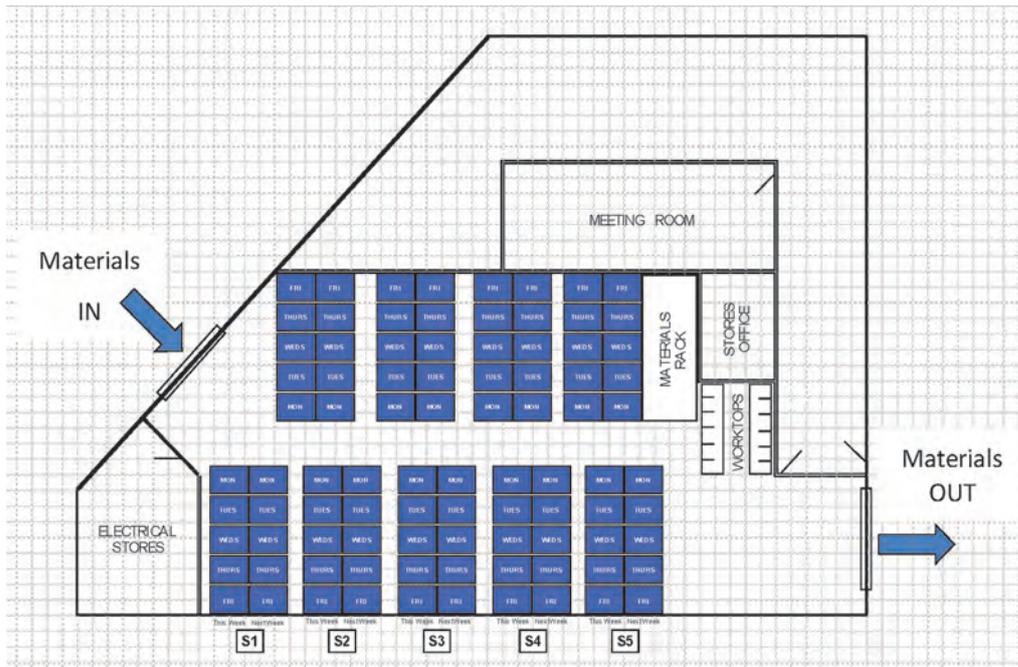


Figure 5.5 Layout of the central stores as a result of the 5S improvement activity

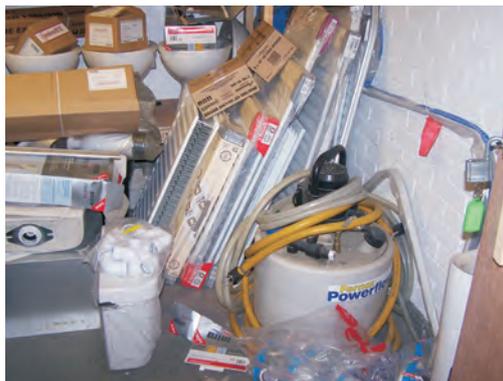


Figure 5.6 5S before



Figure 5.7 5S after

Visual management

6.1 WHAT IS IT?

A picture paints a thousand words – visual management makes things easy to see.

In a Lean-based working environment, it should be easy and quick to understand what is the work situation in terms of status against the plan, whether there are any issues and, if so, who is dealing with them and the status of resolution. Good visual management enables this by communicating a message or an instruction in a quick, easy to understand way, so that the right response or reaction is achieved.

6.2 WHEN AND WHERE TO USE VISUAL MANAGEMENT

Visual management is used in every part of an organisation where there is an immediate need for unambiguous information to be clearly communicated and understood at a glance.

6.3 APPROACH

Visual management is already used in many forms on construction sites, such as notice boards, signs used to indicate dangerous or hazardous situations, colour-coding of fire extinguishers and electrical wiring etc. In a Lean production environment it would also use:

- ▶ team or work area based communication boards to display look-ahead work plans, site layouts marked up to show areas of work and often colour-coded by trade, traffic and material logistics plans, performance measures displayed on charts or graphs, issues and action sheets, improvement successes etc
- ▶ markers to define the amount of work to be completed in a given time period and to show progress of work to an agreed rate of working
- ▶ floor markings to highlight walkways and the location of tools, materials and plant to ensure safe and efficient working
- ▶ shadow boards to organise and ensure availability of tooling.



Figure 6.1
Visual markers to control stock levels and ensure timely replenishment



Figure 6.2
A well-organised site communication centre, where all parties can access vital project information

6.4 TIPS WHEN APPLYING VISUAL MANAGEMENT

- ▶ aim to set a standard in terms of format and content to support familiarity and to support consistency in communication
- ▶ involve people in the development. Design carefully, so that the ‘visual’ needs no interpretation and quickly prompts the right reaction
- ▶ ensure that all information remains current
- ▶ do not let visual information become colourful wallpaper. Use visual boards as the focus for meetings and briefings so that information becomes useful and supportive to the people working on the project.

6.5 BENEFITS TO CONSTRUCTION

Good visual management enables consistent high performance through effective communication processes. This makes it easy to see and understand the plan, the status and achievement to plan, performance, any issues that have affected the plan and/or performance and the status of any actions to resolve any outstanding issues.

Other benefits include:

- ▶ supports safe and efficient working
- ▶ improves quality and productivity
- ▶ helps define the standard and image for site set-up, organisation and operation
- ▶ supports collaborative working
- ▶ helps to establish team ownership for delivery of the project.

Further examples of visual management are given in Case study 6.1 and Figures 6.4 and 6.5

Case study 6.1 Visual management

On an Anglian Water pipeline project the site team put together a project information centre that allowed them to reference important progress milestones to track their programme performance and to have a pipeline 40 km topographical map that wrapped around three sides of the room. This information was used in all of their team meetings to answer questions and orient people to progress.

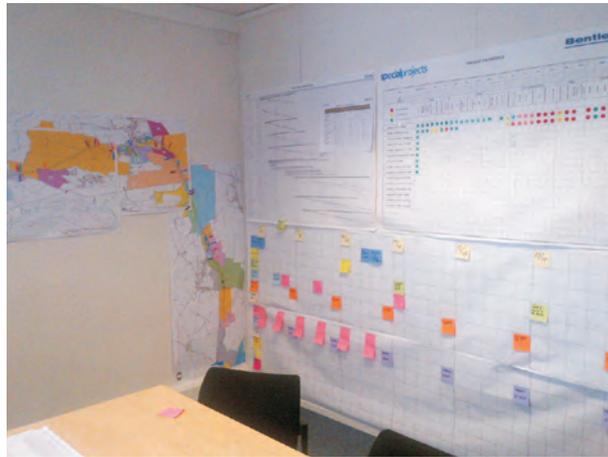
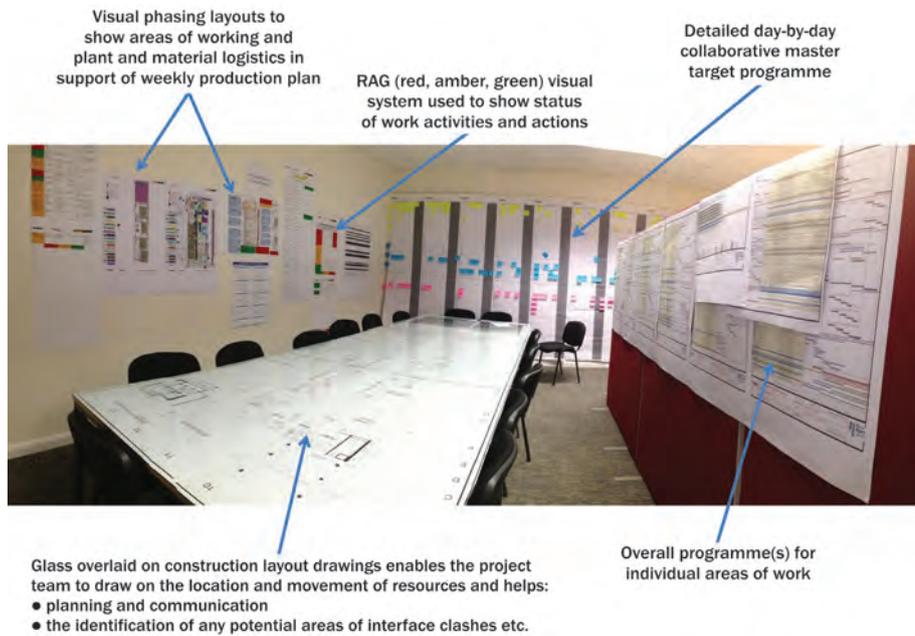


Figure 6.3

Topographical map running around the remaining sides of the room

Left: pipeline map

Right: project map, progress checklist, key production dates on collaborative plan below



Visual phasing layouts to show areas of working and plant and material logistics in support of weekly production plan

RAG (red, amber, green) visual system used to show status of work activities and actions

Detailed day-by-day collaborative master target programme

Glass overlaid on construction layout drawings enables the project team to draw on the location and movement of resources and helps:

- planning and communication
- the identification of any potential areas of interface clashes etc.

Overall programme(s) for individual areas of work

Figure 6.4 *A visual project delivery area used to ensure effective and collaborative planning*



Figure 6.5 *Atkins UK design team using visual management to help plan and control the flow of design information on a high value, complex construction project*

Process improvement

7.1 WHAT IS IT?

Process improvement refers to the activity of establishing effective and efficient processes within a business, a project organisation such as a partnering framework and/or for the processes used to deliver a project. An important aim of process improvement is to reduce the overall lead time through the end-to-end process and will be achieved by applying principles of process challenge and establishing Lean flow.

7.2 WHEN AND WHERE TO USE PROCESS IMPROVEMENT

There are two basic steps related to process improvement:

- 1 **Establishing the ‘current state’:** current state mapping (CSM) is typically used to capture how an existing business or project process is operating. It will provide a clear view of where issues and wastes exist, such as delays, disruptions, bottlenecks, non-‘right first time’ quality, excessive or cumbersome processes etc. CSM provides the basis for designing an improved ‘future state’ process.
- 2 **Defining and then implementing an improved ‘future state’:** future state mapping (FSM) is typically used to design a process incorporating Lean principles so that work flows efficiently through streamlined processes. It is supported by simplified but effective management practices and controls and where roles and responsibilities are clearly defined. Appropriate Lean tools are then used to support the implementation of the improved process (eg problem solving, 5S, visual management etc).

7.3 APPROACH

A common technique used in process improvement is process mapping. Representatives from each part of the process come together to create an agreed picture that describes how work activity flows through the main steps of the process. This can be in terms of how a process is currently working and will reveal opportunities for improvement or in helping to design an efficient process. Maps are typically created on a large wall space using brown paper and Post-It notes.

Various types of process mapping exist with some of the main types described in the following sections.



Figure 7.1
Members from all parties involved in a construction project delivered through a partnering framework, use process mapping to create a picture of existing processes and practices, and were able to identify over 30 opportunities for improvement

7.3.1 Process of activity flow map

Along with the swim lane map (see Section 7.3.2), this mapping technique is probably the most commonly used in helping to map and improve construction related processes. Current state and/or future state maps can be easily created. In its basic form boxes are used to depict process steps and diamonds to show decision points. Arrows are used to link process and decision points to show how work and/or information flows.

7.3.2 Swim lane map

A swim lane map is similar to the process of activity flow map, but with the main difference of mapping the process steps carried out by each person, function or organisation involved in the process. These 'named' individuals or parties are listed vertically on the left of the map and then process steps positioned on the map as they are carried out by each chronologically in time going from left to right. The team involved in completing the map then systematically step through the map identifying any issues or wastes associated with each activity step. This type of map is useful for showing activities that happen simultaneously and also shows who should be doing what and when.

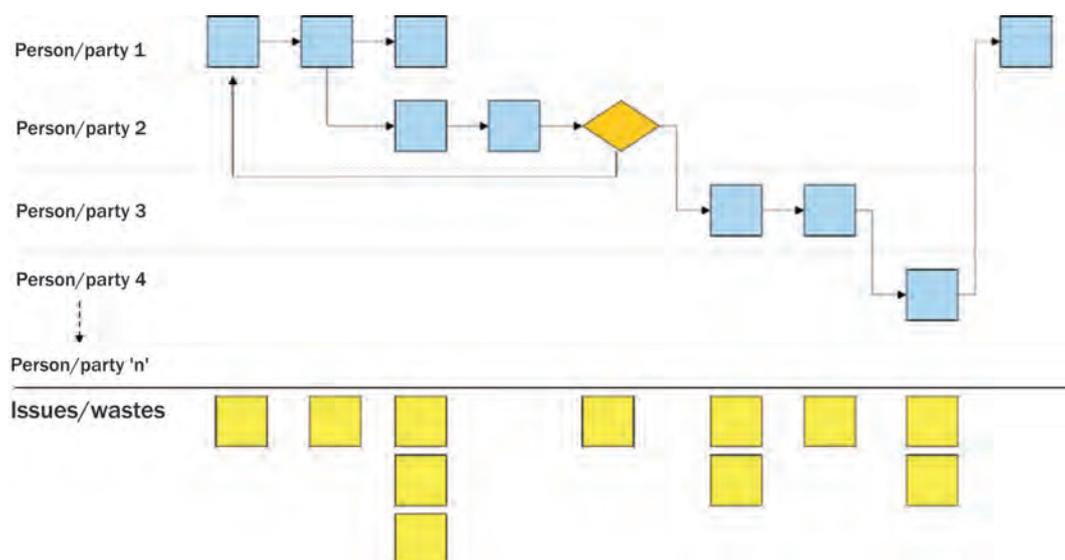


Figure 7.3 Typical format of a swim lane map

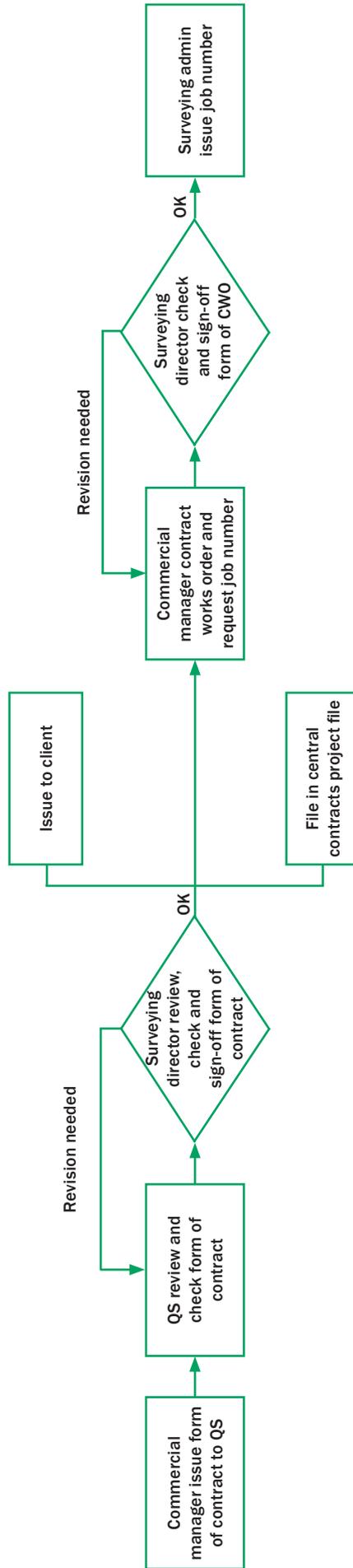


Figure 7.2 An extract of a process flow chart for a setting up a contract and contracts works order for a construction project

7.3.3 Supplier, input, process, output, customer (SIPOC) map

This type of map is used to depict how a product, service or project should be delivered to meet customer requirements (see Figure 7.4). It is a more detailed mapping process to help design a 'customer-focused' process. It is also known as right-to-left mapping in that the starting point is defining what value 'outputs' the customer requires, and then designing the process so that the outputs are created efficiently. To achieve this, the inputs to the process can be clearly defined and set the form that the outputs from the supplier process need to satisfy. This mapping sequence is repeated through all stages of the process.

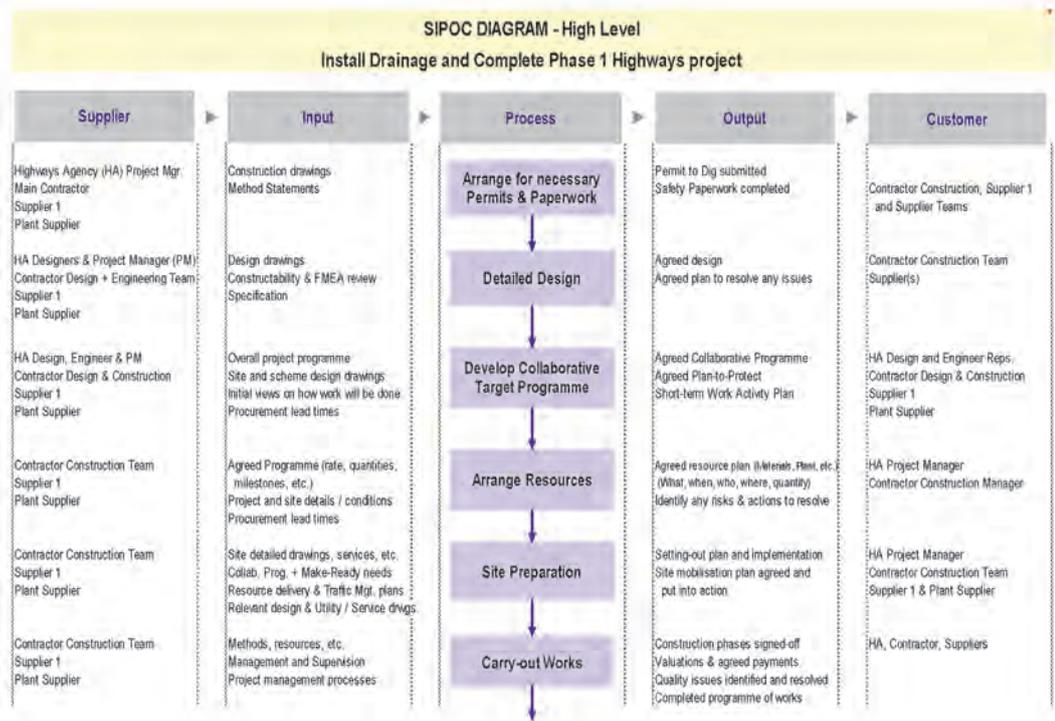


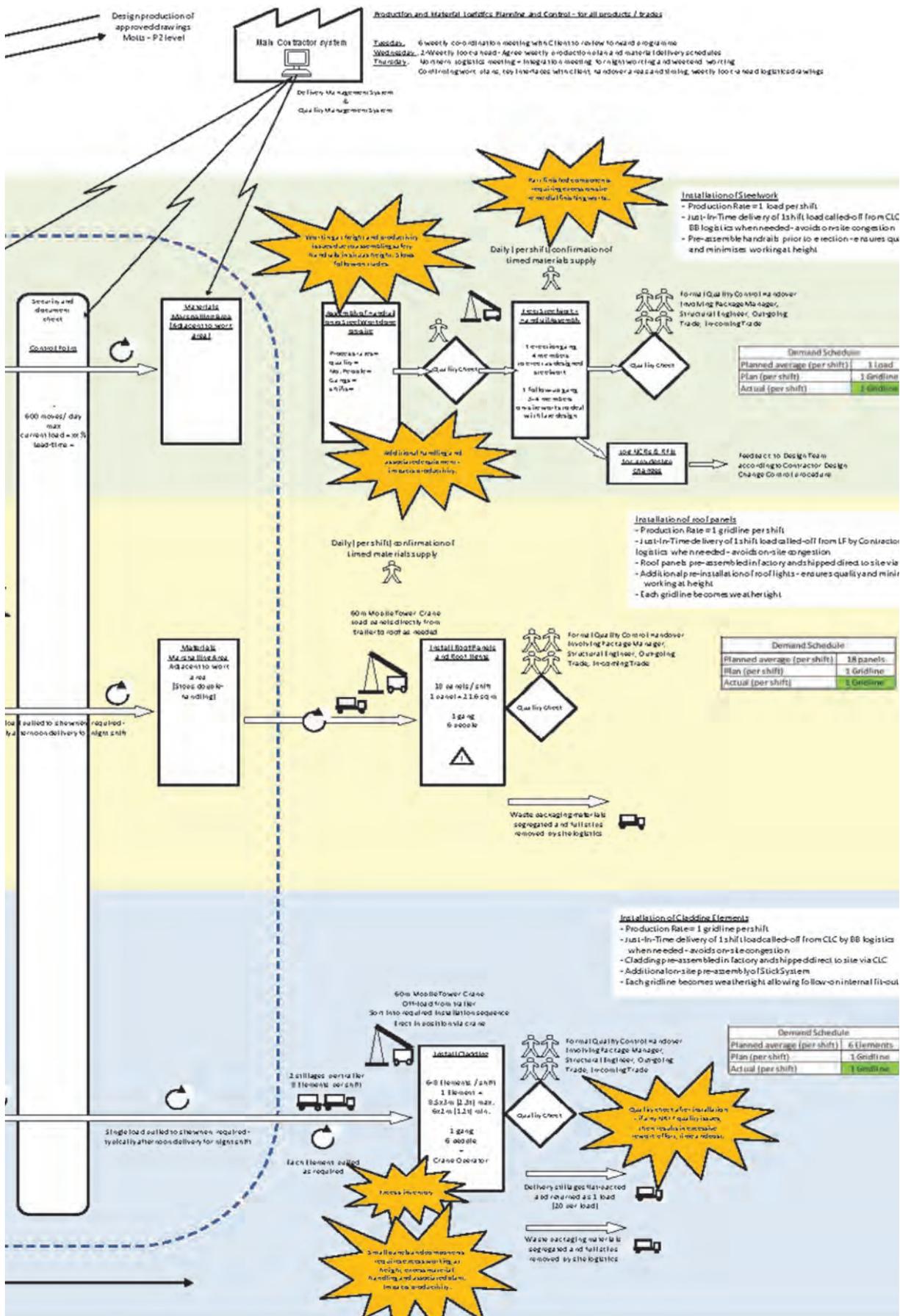
Figure 7.4 An example SIPOC map describing the high-level process related to an infrastructure project

7.3.4 Value stream mapping and analysis (VSM/A)

VSM/A is a Lean technique used to analyse and design the flow of materials and information required to deliver a product, service or project to a consumer. Also known as 'material and information flow mapping', it can be applied to nearly any value stream. Here 'value stream' refers to all processes/stages of the end-to-end of a process.

This form of mapping can take some time and a lot of effort to complete. It would not normally be used to map the processes for a one-off construction project. However, it should be used to map process, information and material flows for high-value projects and where construction activities repeat from one project to another (eg infrastructure, new build housing, facilities maintenance and refurbishment of social housing) or for a long duration project programme (eg a 25-year PFI project).

Current state and future state value stream maps can be drawn. An example high-level current state value stream map is shown in Figure 7.5



Note that by constructing the VSM, the construction team were able to identify opportunities to improve the predictability and productivity of the supply chain, the material logistics delivery process and site operations

7.3.5 Tips when applying process improvement

- ▶ when creating a current state map, seek to map the process as it is actually working, not as you think it should be working. It is important to capture what is happening, including all the issues and wastes
- ▶ it is helpful to mention to the people involved in the mapping activity that it is the process and not the person that is to be mapped
- ▶ aim to quantify the identified issues and wastes in terms of the frequency of occurrence, the magnitude (eg associated actual or typical time lost), the cost etc. This information will help when developing a prioritised improvement plan
- ▶ when possible, carry out some pre-mapping preparation to gather information about the process to be mapped (eg performance data on process time, quality and cost). If data is not readily available, look to implement data collection processes.

7.4 BENEFITS TO CONSTRUCTION

- ▶ provides a clear view of the best way to carry out a project and/or to operate business processes in a way that seeks to maximise customer value
- ▶ improves predictability and productivity through all processes
- ▶ clarifies processes, roles and responsibilities
- ▶ improves value for money and reduces costs of delivery
- ▶ greatly reduces levels of wasted time and effort
- ▶ reduces lead time.

Case study 7.1 Current state and future state process mapping

As part of a lessons learnt and improvement activity, a project team made up of representatives from the client, designer and contractor used process mapping to interrogate existing processes used during the pre-construction phase of a new build school. Two schools were to be built: one school was already in the construction phase, the second had just gone through the concept design phase.

Current state mapping identified process issues and wastes such as duplicated work, lengthy decision making, silo working, several design iterations, over-complicated processes and untimely and incomplete provision of information.

A future state map was defined to deal with the current state issues, resulting in a collaborative project delivery process comprising simplified processes, clearly defined roles and a 'gateway' management process which was used to effectively manage all parties through the pre-construction activities.

Result: a 48 per cent reduction in the time taken to get the second school project to site. The number of meetings and duplicated effort also greatly reduced although the 'value' of this was not quantified.

Operations improvement

8.1 WHAT IS IT?

Operations improvement is about improving the way that work activity is being carried out by removing process waste and ensuring that the 'best' way to complete work activity is being used. Operations improvement aims to reduce the cycle time to complete work activity, improve productivity, ensure 'right first time' quality and support safe working. It covers:

- ▶ identifying and eliminating factors that prevent the effective and efficient completion of work
- ▶ performance monitoring, analysis and improvement
- ▶ optimising the way work is carried out, covering the set-up, organisation and operation of the working environment, the methods used and the type, level and effective use of all forms of resources (people, materials, tools, equipment and plant).

8.2 WHEN AND WHERE TO APPLY OPERATIONS IMPROVEMENT

Operations improvement can generally be applied everywhere, but in practice a random approach seldom produces lasting or significant results. Some important things to guide operations improvement are:

- ▶ bring the operation under study into stability by reducing causes of variation or interruption
- ▶ focus on clear project objectives such as quality, elimination of delays or use of space
- ▶ look for improvements on critical path or near-critical path processes first
- ▶ identify repetitive processes
- ▶ look for early start opportunities
- ▶ do work studies on all processes or activities that indicate significant benefits in productivity and/or the greatest reductions of risk.

These are far from exhaustive but do provide topics for focused improvement.

8.3 APPROACH

8.3.1 Identifying and eliminating production losses

Here the focus is on creating a working environment where the available time for carrying out productive work is maximised through the reduction/elimination of factors (wastes) that delay or disrupt work activities. To achieve this, it is necessary throughout the course of a construction project to capture and analyse any 'production loss' factors that have a detrimental effect on

the accurate and timely delivery of construction works. This data should be collected regularly, for example, it should be logged as part of the daily briefing and weekly production control steps (steps 4 and 5) of the collaborative planning and project management process described in Chapter 3. There are two basic categories of production loss factors:

- ▶ delays and disruptions – time-based wastes
- ▶ non-‘right first time’ quality relating to information, materials, the construction works and the quality standard associated with workmanship.

Production loss data should be analysed regularly (eg weekly or monthly), as shown in Figure 8.1 (page 37). When appropriate, any identified issues should become the focus of a structured problem-solving activity (see Chapter 4), and improvement actions should be put in place to deal with important loss factors.

Tips when identifying and eliminating production losses

- ▶ work closely with those people being asked to record production loss data, explaining it is the ‘process’, which is the focus and that the data will be used to remove those things that cause them to be inefficient
- ▶ establish logging of production losses as part of the daily debrief activity (see step 4 in Chapter 3) as the detail relating to why an issue or waste has occurred will be fresh in people’s minds as will the magnitude of the time, quality, cost or other issues (eg health and safety)
- ▶ ensure collected data is regularly analysed and feed back to the people who collected the data and/or work in the process that the data relates to
- ▶ involve those people working in the process in developing and carrying out improvement actions to resolve the root cause of any important production loss factors.

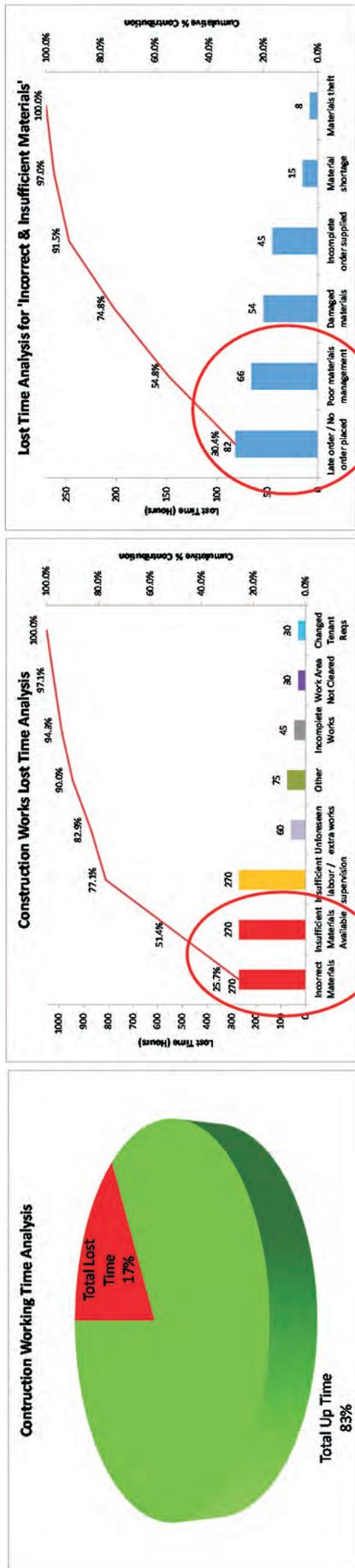
8.3.2 Performance monitoring, analysis and improvement

While not necessarily a Lean ‘tool’, process performance measures (or key performance indicators, KPIs) are a useful way to assess how well a work activity has been carried out. Projects often use numerous KPIs, many of which bear no or little relevance to how well the operational side of project delivery is performing. To improve operations performance, a smaller set of measures relating to quality, delivery (or time), cost and safety is typically used to identify opportunities.

Table 8.1 lists example measures that have been used on construction projects.

Table 8.1 *Quality, cost, delivery and safety measures as defined by CLIP (BRE) following a study of measures associated with operations improvement within the UK construction sector*

Measure	Quality	Cost	Delivery	Safety
Non-‘right first time’	●	○		
Achievement of plan		○	●	
Planned activities complete		○	●	
People productivity	○	●	○	
Budget: adherence		●		
Health and safety	○	○	○	●



What are the factors that contribute to the 17% lost time?

What are the factors that contribute to 'incorrect and insufficient materials'?

Action: investigate and resolve/improve materials ordering and management process

Figure 8.1 Analysis of the lost time experienced on a construction project

Tips to help with performance monitoring, analysis and improvement

- ▶ look to identify a set of ‘measures that matter’, which will clearly identify how well the value-adding processes are performing in terms of quality, delivery and cost
- ▶ link measures to the objectives agreed for the business and/or project (see Chapter 2)
- ▶ ensure that measurement data is regularly reviewed with the people working in the process(es) that the data refers to, to celebrate success and to identify any areas for improvement.

8.3.3 Optimising the way work is carried out

Optimisation is about establishing working practices where work is completed right first time in the most efficient manner. Several Lean tools or activities can be used to achieve this.

Day in the life of (DILO)

DILO is a study of how well a site is operating in terms of set-up, layout, organisation, resource deployment, logistics and a general observation study of the construction works. It is similar to ‘go see’ as defined in Chapter 9. The DILO approach can cover one or more of the following:

- ▶ a general review and critique of a construction site
- ▶ the way that specific work activities are organised and being carried out
- ▶ work shadowing project staff such as the site manager, to identify exactly what work management activities are being carried out. This provides the ability to assess how much real value-adding activity and waste is prevalent at the time of the study.

DILO helps to identify the main wastes and opportunities for improvement, which might cover materials, lost productive time, efficiency, quality and cost. A DILO activity carried out by one of the authors showed that up to a one third of a site manager’s day was spent dealing with rework.

First run study/direct observation of work

A first run study is a detailed observation of work to identify the work activity sequence, work content and the best way to carry out a specific work activity or task, including:

- ▶ efficient working practices
- ▶ the make-up of the team or gang in terms of the required skills and number of members
- ▶ a balanced allocation of work between the team/gang members
- ▶ 5S workplace organisation including the location of materials, tools, equipment and plant (see Chapter 5).

First run/work observation studies can be considered as a detailed version of ‘go see’ (see definition in Chapter 9) and can be conducted at several points in a programme:

- ▶ before the work activity being carried out – for work activities that have been identified as critical path elements of the construction programme and/or those that are deemed to be complex in nature. This form of pre-study can be carried out on a mock-up of the work to be completed
- ▶ at the start of a work activity being carried out on site – particularly useful for work activities that will be highly repetitive through a project
- ▶ in response to an issue and/or drop in expected performance
- ▶ where production rates need to be improved to help pull back losses in a programme.



Figure 8.2
When carrying-out a work observation discuss the approach with the person or gang being observed and avoid any position that will impede normal work operations or compromise health and safety

Work can be observed directly and/or a video camera can be used to record the work activity to enable subsequent analysis by work members. Figure 8.3 shows an example of a work study sheet and related analysis of the observed work activity.

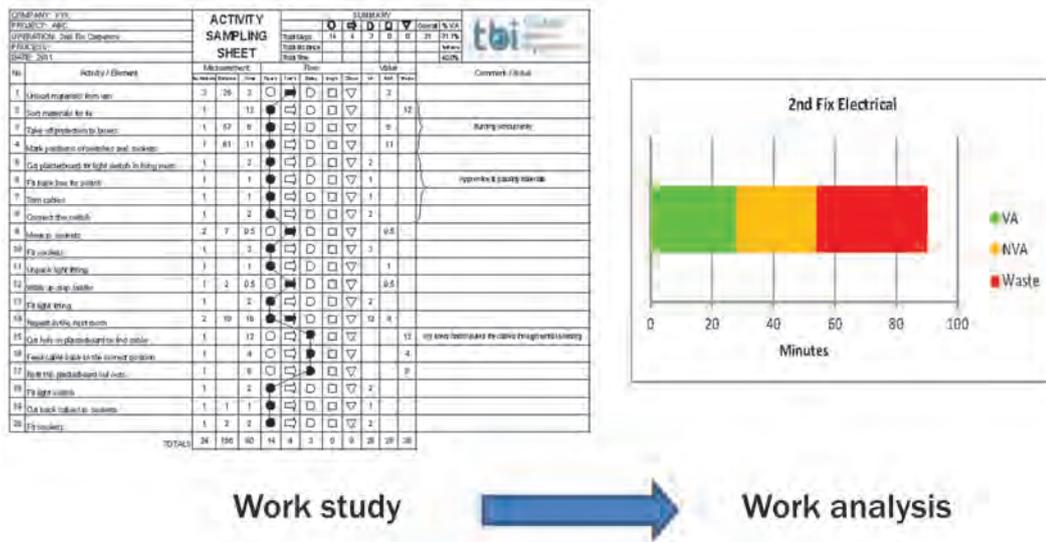


Figure 8.3 An example work study sheet plus related analysis of work

Standard operations

Standard operations (also known as standardised working) is a fundamental element of a Lean approach to doing work safely, efficiently and consistently. It refers to the process of detailing the best way for a work activity to be carried out. This goes beyond the information in a typical method statement, as it will clearly state (task by task) how a work process should be completed. Through review with the people who do the work, care points covering safety, quality and efficiency (or ‘ease’) are defined for each task step.

Figure 8.4 shows an extract of a standard operating sheet (sometimes referred to as a ‘job detail’ sheet) created to define the best method of constructing the timber frame for a new build house. The standard operation was developed by observing the work activity, capturing the work tasks and reviewing with the timber frame gang. Standardised work helps reduce variation in performance from one working team/gang to another and, when applied to construction, is particularly relevant to repeatable work activities.

2-PERSON JOB DETAIL SHEET	Work / Job Description:		Issue Ref. No.:		
	Timber Frame		Issue Date:		
	Outer Wall Erection - Ground Floor		Page 2 of 5		
			Care Point Key		
					Safety  Quality  Knack 

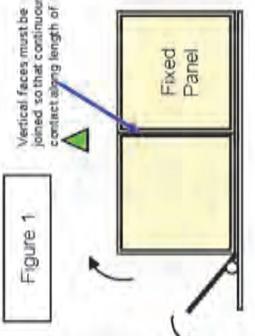
No.	Main Task Step	Care Point	Main Task Step	Sketch
1	Get first outer wall panel and lift to position for erection	<ul style="list-style-type: none"> Clear path from panel stack to erection position. Ensure safe lifting method. Refer to drawing to select appropriate panel Start erection in rear corner of plot - work from back to front of property to aid access 	<ul style="list-style-type: none"> Get first outer wall panel and lift to position for erection 	 <p>Erect first panel starting on one of the rear corners of plot</p>  <p>Vertical faces must be joined so that continuous contact along length of</p> <p>Whist 1st Operator adjusts panel into final position, 2nd operator holds panel steadily & upright</p> <p>Figure 1</p>
2	Secure 1st outer panel in position	<ul style="list-style-type: none"> Nail panel through bottom timber into sole plate, one nail in each end & one in the middle Fit timber stay to hold panel upright 	<ul style="list-style-type: none"> Secure 1st outer panel in position Hold Wall panel upright & in position 	
	Fetch, position & secure 2nd panel	<ul style="list-style-type: none"> Ensure safe carrying & passage as for Step 1 Ensure 2nd panel is in correct position with regard to outer edge of sole plate, is butted-up flush with adjoining face of 1st panel 	<ul style="list-style-type: none"> Fetch, position & secure 2nd panel Hold Wall panel upright & in position 	
3	Nail panel through bottom timber into sole plate, one nail in end next to 1st panel	<ul style="list-style-type: none"> Check position of 2nd panel and that both panels are vertical Nail 2nd panel to 1st panel down vertical inner edge. Remove timber stay from 1st panel Nail 2nd panel through bottom timber into sole plate, one nail at least every 600mm 		
4	Fetch, position & secure 3rd panel	<ul style="list-style-type: none"> Ensure safe carrying & passage as for Step 1 Refer to drawing for panel identification Ensure panel is positioned correctly - flush against sole plate edge & with vertical face of adjoining panel To ensure flush fit between adjoining vertical faces lift bottom corner of panel currently being fitted (Figure 1) Stand on appropriate raised work surface that is properly erected and stable May have to use sledge hammer to help seat panels so as to ensure level top face along adjacent panels Use Hilly Gun for rapid nailing 	<ul style="list-style-type: none"> Fetch, position & secure 3rd panel Hold Wall panel upright & in position 	
5	Nail panels together hammering nails down through top edge of one panel into adjacent panel		<ul style="list-style-type: none"> Ensure appropriate head protection is worn Hold Wall panel upright & in position 	
6	Nail panels at lower outer face through panel overhang into sole plate			
Before using any tools, equipment or plant you must have undergone relevant training and possess evidence that proves competence in the safe use & effective operation such item(s)				

Figure 8.4
An extract of a job detail sheet relating to the erection of timber frame for new house build

Tips to help with work optimisation

- ▶ clearly communicate to the people in the process to be studied the purpose of the activity, focusing on the process and method not the person
- ▶ involve all relevant people who work within the process under focus. Get representatives from the work team/gang to:
 - ▶ do the study and analysis
 - ▶ identify wastes and opportunities for improvement
 - ▶ help develop and then carry out the improvement
 - ▶ define the standard operating procedure (or job detail sheet) – this ensures the best method is defined within the context of the current situation for the work activity and also helps develop ownership.

8.4 BENEFITS TO CONSTRUCTION

- ▶ improves productivity and 'right first time' quality
- ▶ creates a detailed understanding of the work content, methods and activity durations
- ▶ reveals opportunities to improve current working practices
- ▶ can improve balance of work activities between gang members
- ▶ creates real work activity times that can benefit programme performance
- ▶ uncovers the things that prevent the efficient and timely completion of work activities
- ▶ gives insight into the context and environment that people have to work in
- ▶ identifies opportunities for pre-fabrication to aid on-site productivity
- ▶ provides detailed information to help develop the current best standard practice to support productivity and reduce variability in methods and performance
- ▶ creating standard operations (or job details) with those people who carry out the work helps to develop ownership of identifying the best current method and supports continuous improvement.

Case study 8.1 Improving the productivity of steel erection

A steel assembly company was erecting the structural steel for a very large steel frame building. The problem was how to increase productivity to advance the construction completion date. As the steel frame was fully on the critical path, early delivery would support this goal.

The first step was to conduct a precise observation of the build process, supported by videoing of all work. The basic unit of work was a bay made up of four vertical columns going up two floors but the equivalent in height of five. The programmed time for this work was one day. Waste analysis of non-value added work suggested four areas for improvement:

- 1 **Removal of fireproofing paint from the bolts holes:**
Solution: taping of holes before factory painting of beams.
- 2 **Reduction of waiting time for crane loading:**
Solution: pre-slinging of loads using two slings.
- 3 **Crane relocation time:**
Solution: use of light-weight, heavy-duty fibreglass outrigger pads that could be moved by site workers without using a fork lift.
- 4 **Bolt and tool handling by the fitters in the cherry picker baskets:**
Solution: railing boxes inside the working baskets.

Result: these improvements led to a 60 per cent improvement of production.



9

Other tools and techniques associated with a Lean approach to construction

9.1 INTRODUCTION

Table 9.1 lists the range of Lean tools and techniques that can be applied to improve the delivery performance of a construction project. They are related to two categories:

- ▶ tools used to diagnose a project, a process or a work activity to identify opportunities for improvement
- ▶ tools that should be used in the process of improvement.

The sequence of tools presented in this follows a common but far from rigid approach and progression used by the authors, with 'go see' as the first tool to use when work starts. The others may be used in various combinations and sequences depending on what is discovered in the site observation process and the urgency of emerging problems.

The stages of a construction project where a tool has most relevance are shown and the asterisks indicate whether the tool has a primary (**) or a secondary (*) relevance. No asterisk indicates that the tool is generally not applicable to that project phase.

Table 9.1 The range of Lean tools and techniques that can be used to improve the delivery of a construction project

Lean tool/activity	Tool type		Project phase					Chapter in this guide
	Diagnostic	Improvement	Feasibility	Design	Mobilisation	Construction		
'Go See'				**	**	**		
Current state value stream mapping/ process mapping			*	**	**	**	7	
Activity sampling				**	**	**		
Production loss analysis			*	**	**	**	8	
Eight waste analysis			*	**	**	**		
The seven quality tools				**	**	**		
Day in life of (DILO)				*	*	**	8	
Constraint analysis			*	**	**	**		
Quality benchmarking				**	*	**		
Hoshin Kanri			**	**	**	**	2	
Future state value stream mapping/process mapping			**	**			7	
Value management/value engineering			*	**				
Failure Mode Effect Analysis (FMEA)			*	**				
Design for Manufacture and Assembly (DfMA)			*	**	*			
Design standardisation			*	**				
Process design (SIPOC)			**	**	**	*	7	
Gateway planning			**	**	**			
Plan-to-protect				**	**	**		
Lean collaboration planning and project management			*	**	**	**	3	
Theory of constraints				**	**	**		
First run studies/direct observation of work					*	**	8	
5S workplace organisation				*	**	**	5	
Visual management			*	**	**	**	6	
Standard operations				*	*	**	8	
Quick changeover					*	**		
Structured problem solving			*	**	**	**	4	
Line balance/even flow				*	*	**		
Lean logistics					**	**		
Plan-Do-Check-Act (PDCA)			*	**	**	**	4	

9.2 BRIEF DESCRIPTION OF TOOLS NOT DESCRIBED PREVIOUSLY

Where a tool has not been covered previously in this guide, a short description is given as follows.

‘Go see’

It may seem simplistic to suggest that an essential tool of Lean is for managers to go to the work place and observe the work. Yet this is one of the main differences between Lean management and other management assumptions. Sitting in an office looking at data, or having people report to management, will never be an adequate substitute for going out on site. Direct observation should always be the primary source of management information. Acute, precise and fruitful observation of work takes years to develop and is in fact one of the main skills of first class managers but is seldom taught or highlighted. This needs to change and to become a taught, practiced and reviewed management skill.

Activity sampling

This technique is used to understand the range of work tasks being carried out in a process or by a specific person and/or team of people. Information is collected over a defined period of time and analysed to provide a good understanding of the types of tasks, the proportion of time associated with each task and what has delayed or disrupted the effective completion of the tasks. Activity sampling is a useful tool to support current state value stream/process mapping.

Eight waste analysis

The different categories of process waste are defined in Section 1.2. Waste analysis refers to the categorisation of wastes found in a process, system or project with the aim of identifying and prioritising opportunities for improvement.

The seven quality tools

The seven quality tools are a set of graphical techniques used to help troubleshoot issues related to quality. They have been designed to help simplify the collection and analysis of data so as to assist in the quick identification and prioritisation of problems. The tools are:

- ▶ cause and effect (Fishbone or Ishikawa) diagram (see Section 4.3.1.2)
- ▶ check list/sheet
- ▶ control chart
- ▶ histogram
- ▶ Pareto chart
- ▶ scatter diagram
- ▶ flow chart (or run chart).

Constraint analysis

Flow is an important Lean concept that describes the continuous movement of information, people, materials and equipment to the place of work where it is processed within a short period of time, in a controlled manner. It then continues on toward completion and the customer, controlled by the rate of customer demand. Constraint analysis refers to the activity of identifying those activities, processes and practices within the end-to-end production or project process that prevent efficient flow. This is important because each constraint will add time and cost. Once identified, improvements should be made to eliminate or minimise each constraint.

Quality benchmarking

This is a method for establishing a quality example on site for tradespeople to have a clear, unambiguous, physical, accessible example of the standard that is required for comparing and measuring their work. For example, brick panels can be created to represent the quality standard. 'Model' areas or rooms can also be created and used to communicate the desired quality standard as part of the site and work induction process. Quality benchmarks are another example of visual management.

Value management

This process is typically used in the concept design stage of a project. Key representatives, including the user, client, designer and contractor, work together to ensure that the eventual scheme design provides the best value in terms of function, features etc.

Value engineering

This is a process of ensuring that the defined scheme is delivered in the best value way. It looks to achieve specific design features through the best design solution with a focus on capital and operational costs.

Failure Mode Effect Analysis (FMEA)

FMEA focuses attention on an aspect of a critical piece of equipment, construction feature or work process emanating from the design. Its purpose is to review what might go wrong and cause a failure to deliver the desired specification or performance.

Design for Manufacture and Assembly (DfMA)

In construction DfMA is a structured process for interrogating a design to ensure that it can be produced and constructed in an efficient, lowest-cost manner while still meeting the required specifications and functional performance criteria.

Design standardisation

This refers to standardising either the complete design (eg standard house type for new build housing) or a certain element of a scheme design. Its benefits are improved quality, productivity in manufacture of materials and components, productivity of production and reduced cost.

Gateway planning

Gateway planning creates an agreed plan and process of collective management to enable effective and timely delivery of tasks through the pre-construction phases of a project. At the start of a project, all parties work together to define the activities to be completed for each project phase. Important milestones or 'gateways' are agreed. These could, for example, simply reflect RIBA project phases. The timing and the deliverables for each gateway are defined. The agreed gateway plan is used to help co-ordinate and manage activities to their timely completion. Progression from one phase to the next is through a gateway once all deliverables have been satisfied.

Theory of constraints (TOC)

This method is used to identify what process or processes constrain the flow of value-adding work activity within an end-to-end system. The aim is to reduce the level of constraint such that the rate of flow can be optimised in-line with the needs of the customer. The process that is identified as the constraint is defined as the 'pacemaker', because it is this process that governs the rate of

flow through the whole system. When applied to construction projects, TOC aims to minimise constraints and then use the pacemaker to set the beat or rate of production, which can then be used to set the speed of production and task durations within the construction programme.

Quick changeover

This technique helps to reduce the time it takes to move from one work area or activity to the next. Quick changeover will help to ensure productive time is maximised and work areas are clear, clean and tidy for follow-on trades.

Line balance/even flow

Line balance seeks to balance the time different trades take to complete their work tasks against a defined pace or rate of work. It is particularly applicable to repeatable construction activities and will help achieve improved flow and work productivity. Line balance should be considered in the process of developing the best way to carry out work and when developing an agreed programme of works.

Lean logistics

The goal of Lean logistics is the delivery of the right materials, equipment, people and information to the right place, at the right time in the right configuration, the right amount, the right quality with the minimum use of resource including space. The key principles of just in time, pull, flow and continuous improvement are the ideas that drive development and performance for a logistics system and processes that are based on Lean. The use of materials distribution and logistics centres designed to enable just-in-time delivery of small lot size quantities, support the operation of a Lean logistics system where materials are 'pulled' to site in-line with actual material use and progression of construction works.

Lean tools such as 5S, Takt, visual management, value stream mapping, Kanban and others play important elements in understanding the difference between good logistics and high-performance Lean logistics. The importance of Lean logistics is highlighted here while recognising that this is a topic that would require a manual of its own.

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