USE OF A PILOT STUDY TO ASSESS THE DEVELOPMENT OF VIRTUAL FIRST RUN STUDIES (VFRS)

Vince Hackett[1], Christine Pasquire[2], Roy Stratton[3] and Andrew Knight[4]

ABSTRACT

This paper reports some early findings on the implementation of Virtual First Run Studies (VFRS) as part of a number of lean tools in the refurbishment of existing Liquefied Natural Gas (LNG) plant in the North West region of Australia. The VFRS are being used to develop prototypes that will be tested in the FRS phase of the VFRS/FRS cycle.

It is proposed that continuous development of better practice and improved certainty of outcomes can be achieved by the implementation of Virtual First Run Studies (VFRS) and First Run Studies (FRS) as lean interventions in construction projects. This proposal is being tested through experimental design research, undertaken within LNG (Liquefied Natural Gas) refurbishment projects in the Pilbara region of Western Australia. These are projects being undertaken in a remote area under challenging climatic conditions which include high temperatures and cyclones adding to the exposure of the work to uncertainty. Both techniques (VFRS /VRS) are being used in tandem providing an opportunity to develop site specific standardized work packages which can be continuously improved with an emphasis on using the knowledge and experience of the workforce to continuously develop and test standard work packages.

The size and number of projects within the case study are sufficient to allow an experimental design research approach to measure changes resulting from the interventions against a control group. This in itself provides a novel research approach for the construction domain. The research will track an intervention cycle over a 12 month period and this paper will report the initial findings.

[1] PhD Researcher School of Architecture, Design and Built Environment, and Centre for Lean Projects, Nottingham Trent University, Nottingham NG1 4BU, United Kingdom, vince.hackett@ntu.ac.uk

[2] Professor, School of Architecture, Design and Built Environment, Centre for Lean Projects Nottingham Trent University, Nottingham NG1 4BU, United Kingdom, Phone +44 115 848 2859, christine.pasquire@ntu.ac.uk

[3] Reader College of Business Law & Social Sciences, Nottingham Business School of Management Nottingham Trent University, Nottingham NG1 4BU, United Kingdom, Phone +44 115 848 8689, roy.stratton@ntu.ac.uk

[4] Head of construction Professor, School of Architecture, Design and Built Environment, Nottingham Trent University, Nottingham NG1 4BU, United Kingdom, andrew.knight@ntu.ac.uk

KEYWORDS

Prototyping, Virtual First Run Studies (VFRS), First Run Studies (FRS), Lean Implementations, Tacit and Explicit knowledge,

INTRODUCTION

One of the aspects of post-industrial society is the requirement for work to be carried out increasingly by interdependent groups of specialists (Bechky, 2003). Much of the academic research and implementation by practitioners to address this has focused on the codification and transfer of explicit knowledge. As a result organizations develop structures and standard operating procedures to codify and thus transfer knowledge from localized contexts (Huber, 1991; Levitt & March, 1988). However, there is a growing consensus that this approach is insufficient due to the tacit nature of knowledge within many organizations. This tacitness renders attempts to codify, transfer and reuse knowledge ineffective (Nonaka, 1991; Kogut & Zander, 1992). Tacit knowledge, first conceptualised by Polanyi (1958) , is a non-verbalised form of knowledge. It has "stickiness" characteristics due to its contextual, social and cognitive constrains (Nelson & Winter, 1982) which exert a drag on the efficiency of transfer. Bechky (2003, p. 313) notes that " even when knowledge is made explicit in a codified routine, when it is communicated across group boundaries, some organizational members may not understand it because they apply and interpret knowledge within different contexts and words can be incomprehensible to those who do not share an understanding of the context".

Nicolini et al (2012) describe tools or objects used in the transfer of knowledge and understanding in cross-disciplinary collaboration. They refer to these as boundary objects. This concept was developed within the field of science studies (Carlile, 2004; Levina, 2005) and describes boundary objects as being "defined by their capacity to serve as bridges between intersecting social and cultural worlds". A range of objects can become boundary objects, including standardized forms, sketches and drawings (Carlile, 2002), physical objects, prototypes (Star & Greismer, 1989) and narratives (Bartel & Garud, 2003). There is an acknowledgement of the need to be aware of the relative importance of tacit and explicit knowledge usage on construction projects (Robinson, et al., 2005) and to have the understanding that tacit knowledge is of greater strategic importance than explicit knowledge in relation to business performance (Chen & Mohamed, 2010). The construction industry has long been criticized for its fragmented nature (Green, 2011) and in particular for the separation of design and construction (Lautana, 1997). These characteristics create many interfaces across which knowledge and understanding are frequently distorted and generate a need for effective boundary objects as defined above.

It is proposed that Virtual First Run Studies (VFRS) and First Run Studies (FRS) are a form of boundary object that have the potential to generate the high levels of common understanding (Pasquire & Court, 2013) required for effective project delivery. VFRS & FRS are forms of prototyping - a boundary object widely used within the manufacturing sector to aid understanding of and knowledge about product function, design and assembly as a proof of concept exercise. The use of prototyping is widespread in many industry sectors but has been overlooked by the construction industry until very recently – the growing uptake of lean approaches is bringing with it a greater use of mockups or first run studies as a way to learn about how aspects of the construction work are going to interface and to test the buildability of the design. A valuable output of V/FRS is the development of standard work approaches that form the basis improvement initiatives. However, a belief that "each project is a prototype in itself" has militated against using standardized approaches to work, thus contributing to process waste and acting as a barrier to learning and continuous improvement. Running VFRS in tandem with FRS enables the Virtual exercise to form a prototype with the First Run through the process in reality forming the testing or proof of concept stage for the standard work. There is a degree of anecdotal evidence suggesting that this VFRS/FRS combination is used as a lean construction approach. Whilst Nguyen et al. (2009) report on its use in the development of solutions for a viscous damping beam and Salem, et al, (2006) notes its use as a lean tool, a literature review reveals a paucity of academic papers reporting anything further. The aim of this paper is to begin to address this gap in the literature and contribute empirical evidence from a preliminary study that observes the role and impact VFRS as a means to identify improvement and develop sound standard work packages.

VIRTUAL FIRST RUN STUDIES AND FIRST RUN STUDIES (VFRS/FRS)

Ballard and Howell (1997, pp. 125-126) say that the VFRS/FRS exercise should be carried out as follows in order to develop standard work packages:

Plan

1. Select the work processes to study.
2. Gather the people for the VFRS who can provide input and impact.
3. Collaborate using past experience to develop good practice.
4. Anticipate hazards and specify preventions.
5. Assign optimum labour, tool and equipment resources.

Do

6. Try out the prototyped work in the FRS phase.

Check

7. Describe and measure what actually happened, process steps, durations, errors, omissions and reworks, near misses and hazards, resources used and outputs.

Act

8. Reconvene the team, especially those involved in carrying out the work. Review data and share experiences. Continue to refine the standardised work.
9. Communicate the improved standardised approach to the workforce.

Ballard and Howell (1997, p. 215) note that "the intent is to thoroughly plan and study first run studies of operations, using past studies as guidelines and producing standard work method designs for use on the project. This experiment – based approach produces a tested method that can be taught to all crews, thus reducing cost, errors and accidents... once workers see that you are interested in finding better ways of doing work, they will develop and share their ideas". The "plan" part of this framework has been adopted as the basis for the research reported here and its application is tested through the case study and action research.

RESEARCH METHODOLOGY

Field research was undertaken within an organization that owns and operates oil and gas facilities within Australia and globally and was embedded within a business unit that is undertaking the refurbishment of existing LNG processing trains in Western Australia. The refurbishment work has been underway for two years and will continue for another eight in order to extend the operating life of the plant by twenty five years. A proportion of the refurbishment work is undertaken during the normal operation of the plant and some during shut down periods. In both cases the work is highly constrained. The start of the primary research has coincided with a change event which includes the introduction of an EPCM (Engineering, Procurement Construction Management) procurement model along with the appointment a new EPCM contractor and second tier contractors. The intention to provide authoritative, empirical evidence about the effects of an intervention in practice has led to the selection of three research phases each with distinct methods. These are

- *Case Studies*; These have been used in an exploratory stage to determine the current state so as to establish the need for implementation of VFRS, FRS and other lean interventions. However only the VFRS is reported here as the other interventions are on-going.
- *Pilot Studies*: after evidence of opportunity for improvement was identified a pilot study was carried out using an action research approach in which VFRS were implemented as interventions.
- *Experimental Design Research*: The final phase aims to establish and explain causality of the changes observed. This phase of the research has not yet taken place but is will involve the randomized assignment of units to conditions where on average, the control and intervention groups are probabilistically similar to each other (Shadish, et al., 2002). This method requires a number of teams to be working under the same conditions so that effect of an intervention within the activities of one team can be clearly identified and attributed to the intervention when compared to the control team/s. The purpose of this research will be to test the core hypothesis that people process variables fully mediate the link between lean implementation and productivity/efficiency outcomes. The hypothesised causal chain (figure 1) proposes that the use of the lean implementation (LI) tools will impact the people process variables which in turn effects productivity outcomes. The people process variables include cognitive, affective and attitudinal constructs (Figure 1).

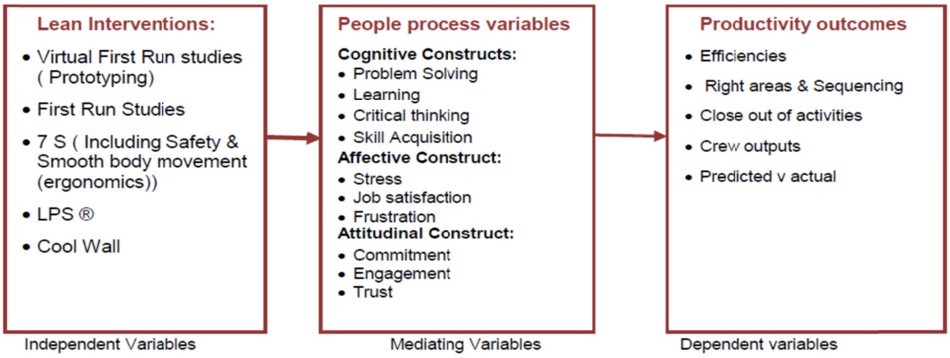

Figure 1: Causal Chain

CASE STUDIES

Case studies are a relevant method to use when a "how" or "why" question is being asked in a contemporary set of events over which the investigator has little or no control (Yin, 2009). This approach can provide a source of insights and ideas (Fellows & Liu, 2008). The purpose of this case study was to establish a current state from which to identify the processes to be studied thus addressing point 1 in Ballard & Howell's (1997) list of activities to be undertaken in VFRS/FRS. The case study was undertaken over two x three week long periods three months apart during which the researcher was embedded within the organisation as an impartial and non-participant observer at both the head office and at the refurbishment site. The research role was presented to employees as a University research exercise to emphasise impartiality. To this end data from several sources was collected including:

- *Documents and artefacts:* The documents located revealed detailed data and information on the refurbishment work carried out over the previous year. These consisted of productivity analyses, documentation detailing descriptions of how work was undertaken, project variations information (PVI) providing data on delays and reasons and "lessons learned" collated at the end of 2013.
- *Detached Observation;* This involved "watching from the outside" (Proverbs & Gameson, 2008). This form of observation allowed the researcher to capture an unbiased and accurate impression of the daily actions and practices of work crew, management and support staff on the worksite across the full working day. This observation work included attending daily meetings held by the oil & gas company (the client) the EPCM contractor and the second tier contractors. Time was also spent on site alongside engineers, supervisors and workers as refurbishment work was being carried out.
- *Interview:* Informal interviews represented an important method in developing an understanding of people's experiences, views and knowledge and involved guided conversations (Rubin & Rubin, 1995) with questions used to pursue a particular line of enquiry. These spontaneous informal interviews occurred regularly during the observation of the work and proved a good source of information about what the work entailed and people's experiences and attitudes.

Findings

The analysis of the data and information demonstrated that there was a high degree of waste and non-value activities (NVA) embedded within the current work process. It was clear that the principle cause of time delays (outside of cyclones) was poor planning (see Figure 2) and as such suggests an opportunity exists to improve planning through lean techniques one of which is VFRS.

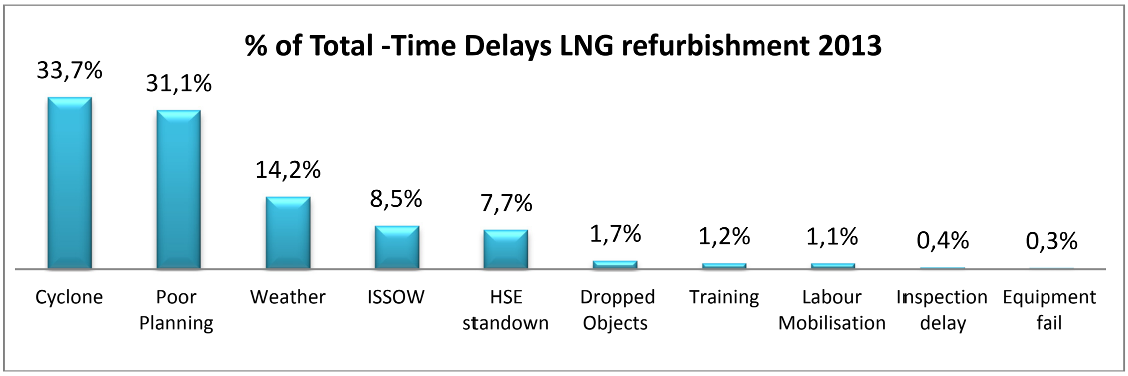

Figure 2: Data collated from Project Variation Information (PVI) data.

As a form of prototyping, a VFRS can improve planning by revealing potential constraints and interruptions to workflow as well as creating innovations within the proposed processes. The development of standard work as a result of VFRS also helps with planning by facilitating a more predictable and reliable work flow. Other issues identified were lack of organisation, unclear procedures and poor communication, all of which would be improved by undertaking VFRS to develop standard work. The waste identified point to a somewhat disorganised work approach and the graphs (Figures 3 & 4) categorises the time expended over the course of a working day.

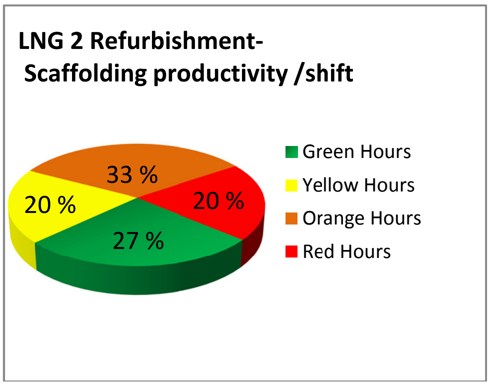

Figure 3: Daily hours split scaffolding

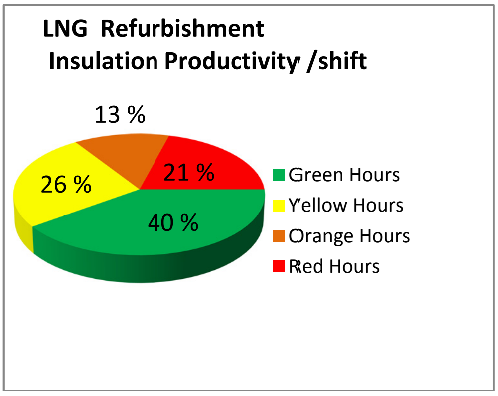

Figure 4: daily hours split insulation crew

Hours in the 12 hour working day are split as follows:

- *Green* –Production hours: potentially all value adding (VA)
- *Yellow* – Hours expended that are non-value adding (NVA). The wastes include waiting and unnecessary movement caused by poor planning and communication.
- *Orange* - NVA hours including waiting and transportation delays due to the locations of the welfare facilities and waiting for permitary.
- *Red* – Downtime hours accounted for by meal breaks and HSE requirements. These hours cannot be altered due to statutory and corporate requirements.

Transportation: Time spent transporting work crews between the welfare facilities and the workface (orange hours –figures 3 & 4). There is risk of explosion on LNG plant so welfare facilities are situated at some distance from the plant. Delays were caused by inefficient and disorganised transportation to and from these welfare facilities to the workface zones.

Movement and Waiting: Excess movement consisted of the time spent by work crews searching for equipment, material and plant and organising its transport to the appropriate work zones. Waiting included permitary delays and waiting for work fronts to become available.

Outcomes: The transportation waste identified was excess movement and waiting for permitary and work fronts to become available. This demonstrated that there was no obvious standard approach to transportation of workers to and from the workface or for workforce organisation when at the workface itself. The analysis of the previously documented "lessons learned" exercise pointed to issues with duplication of effort and lack of clarity of documentation. A breakdown of the delay caused by variations over a one year period showed that 31% of delay was caused by poor planning and organisation. These issues were all felt to be sufficient justification to proceed with a pilot study which implemented a VFRS in order to develop a robust, documented approach with clear guidelines for its use.

PILOT STUDIES

The LNG train refurbishment work package used for the pilot study was the targeted inspection (TI) campaign. This scope involves exposing and inspecting pipe work (Figure 5) and vessels (Figure 6) to gather data on rates of corrosion and deterioration. Just over 250 inspections were carried out between Jan 2014 and March 2014. The results of these inspections provide information which informs the scope of the refurbishment work that will be executed during a whole plant shutdown. Each TI represents a mini-project in which scaffold was erected for access, cladding and insulation was removed, the inspection undertaken, the insulation and cladding replaced and the scaffolding removed. Each TI group consists of typically 12 people, including the scaffolders, metal workers, insulators and an inspector. This pilot study was carried out with two teams in the final four weeks of the TI campaign.

Figure 5 LNG pipe work inspections

Figure 6 LNG vessel inspections

The area targeted for the VFRS implementation was the scaffolding and associated work (Figure 5). The VFRS took the form of workshops attended by inspectors, project engineer, the superintendent and the field supervisors responsible for the scaffolding, cladding and insulation. During these workshops a number of areas of improvement were identified. A partially pre-populated form (Figure 6) was used to provide a focal point for discussion and decision making by the group. The form used a reverse phase scheduling approach in which began with the end point of the process (disposal of waste) and worked backwards to the start point (protection of plant) searching for new approaches and innovation along the way.

Package: WASTE REMOVAL
Date: 28/3/2014 Location: KGP-DOMGAS
Work type: WASTE REMOVAL DURING INSPECTIONS
Attendees: COLIN, FIONN, JIM, RUDY, RAY, RORY GREG & VINCE.

No	Activity description	Possibilities	Choices-Why?	ISSOW permitry	Risk To plant	Outcomes/Comments
1	Disposal of waste	Skip & offsite Compact & skip Recycle				
2	Disposal of waste to ground	GIN WHEEL	CHUTES			RESTRICTED ACCESS NEGATES CHUTES. SEGREGATION OF WASTE AN ISSUE.
3	Disposal To ground		WHEEL BARROWS WHEEL BINS			WHEEL BINS NOT CONDUCIVE TO GRAVEL
4	SCAFFOLD		COLOUR CODING			APPEARS TO BE A GOOD SYSTEM.
5						
6						
7	Remove insulation	SHROUD THE AREA FOR FIBRES	BIDIUM & SHADE CLOTH PLY USED FOR GAPS.			
8	Remove Cladding		SITE BENCHES SITE W/SHOP.			SATELLITE WORKSHOP HAND ROLLERS, SWAGE & ELECTRIC SHEARS.
9	Protection					

Figure 6 VFRS form - boundary object

The purpose of the VFRS is to transfer knowledge so as to develop common understanding across the disciplines, using objects and/or tools called boundary objects (Nicolini, et al., 2012). Carlile notes (2004, p. 614) that boundary objects acquire "a deep emotional holding power and generate intimate attachments that create social bonds". Retention of the handwritten forms in the "raw state" without transcription and typing up was felt to preserve personal attachment strengthening their power as a boundary object. The reverse pass document proved to be a useful boundary object facilitating the transfer of knowledge and experience between the interdependent groups of specialists. There was an initial reluctance however by the field supervisors to the idea of proposing new practice and innovation and a number of workshops were needed to arrive at some workable solutions that could be tested in a FRS phase (yet to be conducted). A further boundary object of narratives and story-telling proved to be a particularly powerful in uncovering the reasons for the reticence. The scaffolding is considered a high risk activity. This is because there are numerous points on trains such as switches, gauges, telemetry and instrumentation which can cause a train to trip if struck by the scaffold tube during the erection process. The plant is an integrated system and a single trip event will cascade through the plant causing a number of trains to shut down, taking up to twenty four hours to restart at massive cost to the company. The learning outcome was that in cases such as scaffolding and its periphery, follow up workshops are necessary in order to develop prototypes that do not produce unintended consequences and where additional experts such as the train operators are present to provide their input and knowledge.

Figure 7 Trip points (pink ribbons)

A number of other lessons were learned during the process of undertaking the workshops, which were

- Identify the integrated team that will be involved in the VFRS.
- Work on a real piece of work that can be trialled on site.
- Form the relationships with the participants before the meeting.
- Give a clear description of the system and proposed outcomes expected at the session before it starts.
- Only have the decision makers at the VFRS/FRS process.
- Be prepared to have a number of VFRS workshops and include other specialists with required knowledge and experience.

These lessons supplement the list of activities identified by Ballard and \Howell (1997) under the task of "*plan*".

CONCLUSIONS

The work on the development of the process for undertaking VFRS has confirmed and added to the earlier process identified by Ballard and Howell (1997). The need to undertake an examination of the current state in order to define the process to be studied was evidenced by the exposure of the principal areas of waste and NVA within the LNG refurbishment activity. The identification and examination of boundary objects as a mechanism used in the knowledge transfer between interdependent teams has provided some specific objects and tools that can be helpful in the execution of VFRS in general and in LNG refurbishment in particular. The outcome of pilot study highlighted some issues that need to be addressed when undertaking the VFRS in order to develop continuous improvement prototypes, including overcoming the reticence of participants by identifying the root cause. In the case of LNG refurbishment this centred on the nature of risk in these contracts and the requirements to understand and mitigate risk during the VFRS process.

The boundary objects already existing within the lean tools allow interdependent groups to develop continuously and learn from each other. This provides an incentive to use and embed the tools to develop incremental continuous improvements as the refurbishment work progresses forward.

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