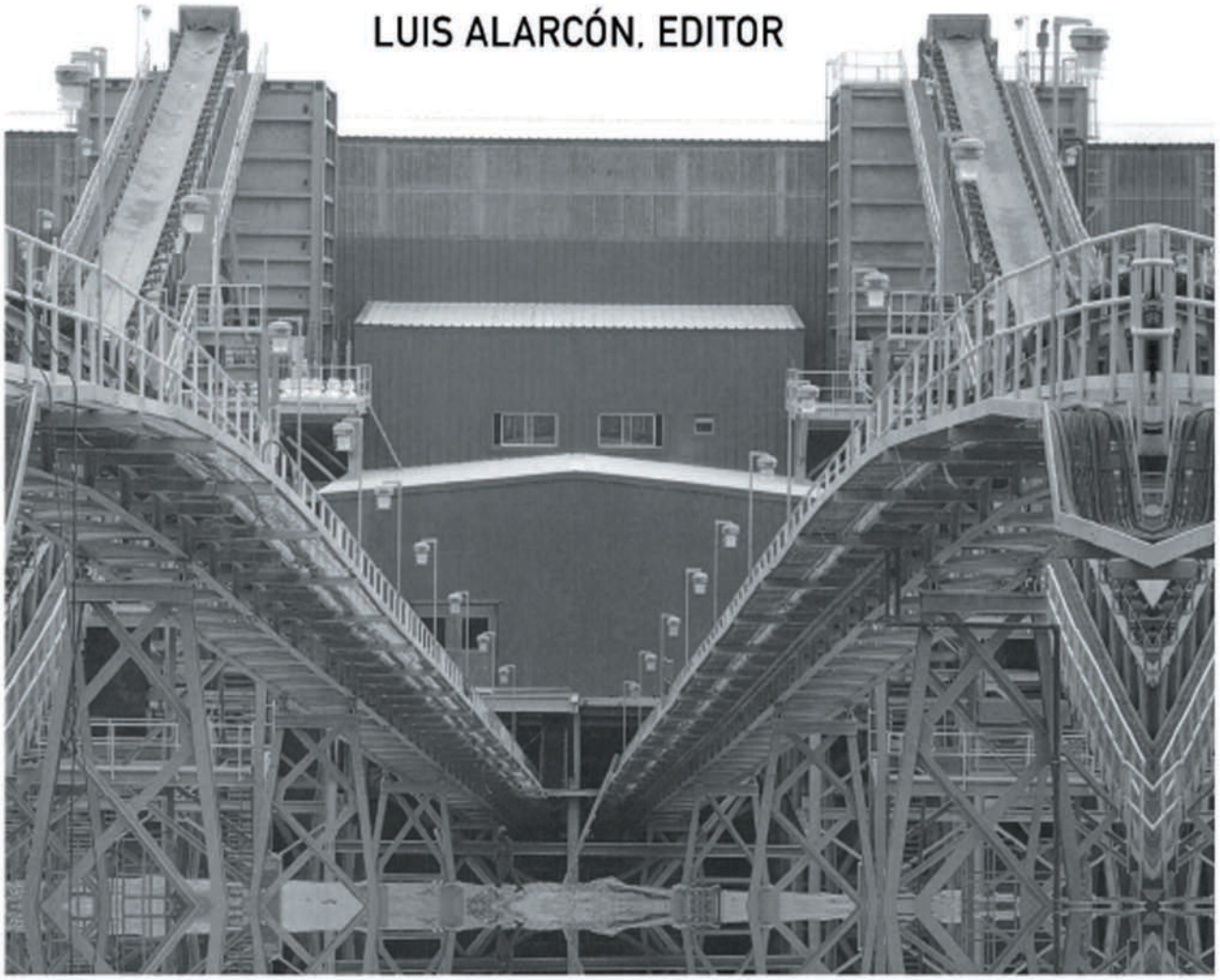
LEAN CONSTRUCTION

LUIS ALARCÓN, EDITOR



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Taylor & Francis
Taylor & Francis Group
LONDON AND NEW YORK

Published by Taylor & Francis
2 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN
270 Madison Ave, New York NY 10016

Transferred to Digital Printing 2007

ISBN 90 5410 648 4

Publisher's Note
The publisher has gone to great lengths to ensure the quality of this reprint but points out that some imperfections in the original may be apparent

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Preface

In the last two decades, great improvements in performance have been observed in manufacturing. In particular, lean automobile industry is now using less of everything: half the manufacturing space, half the human effort in factory, half the product development time, half the investments in tools. In general, significant improvements in all performance indicators have been observed simultaneously, challenging classic paradigms. All these improvements have not been the product of a radical or sharp change of technology but the result of the application of a new production philosophy which leads to "Lean Production". The new production philosophy is a generalisation of such partial approaches as JIT, TQM, time-based competition, and concurrent engineering. Its adoption is expected to change almost every industry bringing revolutionary changes to the way we work. So far, in construction, lean production is little known but several companies have started to explore applications of the concepts of lean production to construction. Even if only a small fraction of the gains observed in manufacturing were realised in construction, the incentive to apply these concepts would be tremendous.

The new production philosophy recognises two types of activities in a production system: conversions activities which add value to the material or piece of information being transformed into a product and flows (inspection, waiting, moving), through which the conversion activities are bound together but which do not add value. The improvement of non value adding flow activities should primarily be focused on improving reliability if not reducing or eliminating them, whereas conversion activities should be made more efficient. In construction, management attention has been focused on conversion processes and flow activities have not been controlled or improved, leading to uncertain flow processes, expansion of non value-adding activities, and reduction of output value. The opportunities of improvement are enormous. During the last four years an increasing number of researchers have joined efforts to investigate the implications of lean production to construction. They have shared their views and experiences with people from the industry, suggested new approaches to lean construction and worked to advance a new theory of production in construction.

This book summarises the new and evolving conceptualization of lean construction by collecting the work developed by members of The International Group on Lean Construction (IGLC) during the last three years. The authors, who are from different backgrounds and include people from the industry and the academia, have covered theoretical aspects as well as relevant areas for lean

construction, such as performance measurement, improvement tools, implementation issues, and case studies. The result is a challenging exchange of ideas and experiences which include stories of success and also some of failure.

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November, 1996

Acknowledgements

There is some key people who must be acknowledge for their contribution to the development of research on Lean Construction. The pioneer work of Lauri Koskela, from VTT, Finland, was an important milestone in developing a stream of research on Lean Production applied to Construction. In 1992, Lauri wrote an inspiring report on Lean Construction during his visit to Stanford University. Then, upon his return to Finland, he organised the First Conference on Lean Construction which was held in Espoo, Finland, in 1993. The Second Conference on Lean Construction was hosted by the Universidad Católica de Chile, in Santiago, Chile in 1994. Glenn Ballard, from the University of California, Berkeley, and Gregory Howell from the University of New Mexico, Albuquerque, have been also key contributors and enthusiastic promoters of the research on Lean Construction. Greg and Glenn hosted the Third Conference on Lean Construction which was held in Albuquerque, NM, USA, in 1995.

The Corporación de Investigación de la Construcción of the Chilean Chamber of Construction is acknowledge for its support to the organization of the Conference on Lean Construction in Chile and for supporting the research in this area, in the Construction Engineering and Management Program at the Universidad Católica de Chile.

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Lean production in construction*

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ABSTRACT: In manufacturing, great gains in performance have been realized by a new production philosophy, which leads to 'lean production'. This new production philosophy is a generalization of such partial approaches as JIT, TQM, time-based competition, and concurrent engineering. In construction, lean production is little known. The concepts, principles and methods of lean production are reviewed, and their applicability in construction is analyzed. The implications of lean production to construction practice and research are considered.

1 INTRODUCTION

The chronic problems of construction are well-known: low productivity, poor safety, inferior working conditions, and insufficient quality. A number of solutions or visions have been offered to relieve these problems in construction. Industrialization (i.e. prefabrication and modularization) has for a long time been viewed as one direction of progress. Currently, computer integrated construction is seen as an important way to reduce fragmentation in construction, which is considered to be a major cause of existing problems. The vision of robotized and automated construction, closely associated with computer integrated construction, is another solution promoted by researchers.

Manufacturing has been a reference point and a source of innovations in construction for many decades. For example, the idea of industrialization comes directly from manufacturing. Computer integration and automation also have their origin in manufacturing, where their implementation is well ahead compared to construction.

Currently, there is another development trend in manufacturing, the impact of which appears to be much greater than that of information and automation technology. This trend, which is based on a new production philosophy, rather than on new technology, stresses the importance of basic theories and principles related to production processes (Shingo 1988; Schonberger 1990; Plossl 1991). However, because it has been developed by practitioners in a process of trial and error, the nature of this approach as a philosophy escaped the attention of both professional and academic circles until the end of 1980's.

In construction, there has been rather little interest in this new production philoso-

*Presented on the 1st workshop on lean construction, Espoo, 1993

phy. The goal of this paper is to assess whether or not the new production philosophy has implications for construction. The paper is based on a more detailed study (Koskela 1992a).

2 LEAN PRODUCTION

2.1 *Origins of lean production and the new production philosophy*

Since the end of 1970's, a confusingly long array of new approaches to production management has emerged: JIT, TQM, time based competition, value based management, process redesign, lean production, world class manufacturing, concurrent engineering.

After closer analysis, it transpires that the above mentioned management approaches have a common core, but view this from more or less different angles. This common core is made up by a conceptualization of production or operations in general; the angle is determined by the design and control principles emphasized by any particular approach. For instance JIT stresses the elimination of wait times whereas TQM aims at the elimination of errors and related rework but both apply this angle to a flow of work, material or information.

Thus, a new production philosophy is emerging through generalization of these partial approaches, as has been suggested recently by various authors (Schonberger 1990; Plossl 1991). The new production philosophy, regardless of what term is used to name it (world class manufacturing, lean production), is the emerging mainstream approach practised, at least partially, by major manufacturing companies in America, Europe and Japan. The new philosophy has already had a profound impact in such industries as car manufacturing and electronics. The application of the approach has also diffused to fields like customized production, services, administration and product development.

The conception of the new production philosophy evolved through three stages: It was viewed as a tool (like kanban and quality circles), as a manufacturing method (like JIT) and as a general management philosophy (referred to, for example, as world class manufacturing or lean production). The conceptual and theoretical aspects of the new production philosophy are least understood. However, without conceptual and theoretical understanding the application of methods is bound to remain inefficient and haphazard.

In Figure 1, an attempt for a consolidation of the new production philosophy is presented. The various levels are analyzed in the following.

2.2 *Conceptual framework*

The core of the new production philosophy is in the observation that there are two aspects in all production systems: Conversions and flows. While all activities expend cost and consume time, only conversion activities add value to the material or piece of information being transformed into a product. Thus, the improvement of non value adding flow activities (inspection, waiting, moving), through which the conversion activities are bound together, should primarily be focused on reducing or eliminating

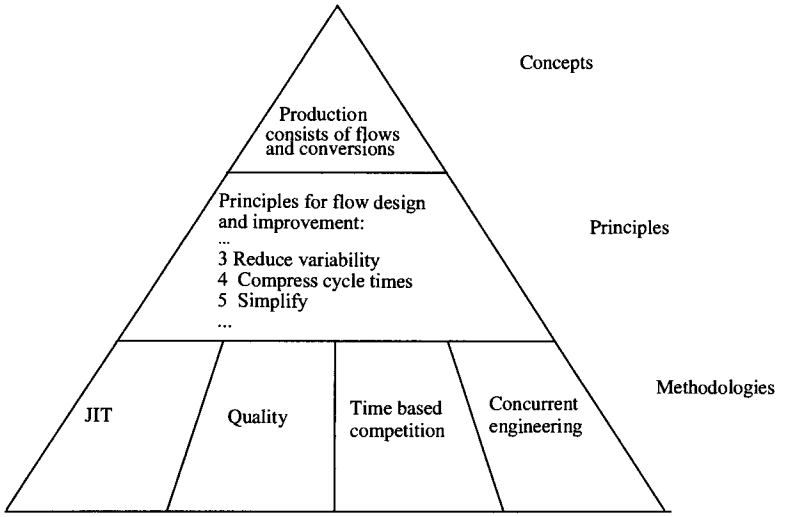

Figure 1. Different levels of the new production philosophy.

them, whereas conversion activities should be made more efficient. In design, control and improvement of production systems, both aspects have to be considered. Traditional managerial principles have considered only conversions, or all activities have been treated as though they were value-adding conversions.

Due to these traditional managerial principles, flow processes have not been controlled or improved in an orderly fashion. We have been preoccupied with conversion activities. This has led to complex, uncertain and confused flow processes, expansion of non value-adding activities, and reduction of output value.

Material and information flows are thus the basic unit of analysis in the new production philosophy. Flows are characterized by time, cost and value.

2.3 *Principles*

In various subfields of the new production philosophy, a number of heuristic principles for flow process design, control and improvement have evolved. There is ample evidence that through these principles, the efficiency of flow processes in production activities can be considerably and rapidly improved. The principles may be summarised as follows (Koskela 1992a):

1. Reduce the share of non value-adding activities (also called *waste*);
2. Increase output value through systematic consideration of customer requirements;
3. Reduce variability;
4. Reduce cycle times;
5. Simplify by minimizing the number of steps, parts and linkages;
6. Increase output flexibility;
7. Increase process transparency;
8. Focus control on the complete process;

9. Build continuous improvement into the process;
10. Balance flow improvement with conversion improvement;
11. Benchmark.

In general, the principles apply both to the total flow process and to its subprocesses. In addition, the principles implicitly define flow process problems, such as complexity, intransparency or segmented control.

Experience shows that these principles are universal: They apply both to purely physical production and to informational production, like design. Also, they seem to apply both to mass production and one-of-a-kind production.

2.4 *Methodologies and tools*

Among the methodologies for attaining lean production are the following most important:

- Just in time (JIT);
- Total quality management (TQM);
- Time based competition;
- Concurrent engineering;
- Process redesign (or reengineering);
- Value based management;
- Visual management;
- Total productive maintenance (TPM);
- Employee involvement.

Most of these methodologies have originated around one central principle. Even if they usually acknowledge other principles, *their approach is inherently partial.* Thus, for example, the quality approach has variability reduction as its core principle. Time based management endeavors to reduce cycle times. Value based management aims at increasing output value.

In the framework of all these methodologies, useful techniques, tools and procedures have been developed. For example, such techniques as quality circles and the 7 quality tools (fishbone diagram, Pareto-diagram etc.) are used in TQM.

2.5 *Comparison between conventional production and lean production*

What is the conventional production philosophy being now replaced by the new philosophy? It is the paradigm of industrial mass production, which evolved in the beginning of this century. The most important differences between the conventional and the new philosophy are summarized in Table 1.

The results of the implementation of the conventional and the new production philosophy are schematically illustrated in Figure 2.

Conventional production is improved by implementing new technology, primarily in value adding activities, to some extent also in non-value adding activities (like automated storages, transfer lines and computerized control systems). However, with time, the cost share of non-value adding activities, which are not explicitly controlled, tends to grow: production becomes more complex and prone to disturbances.

In lean production, non value-adding activities are explicitly attended. Through measurements and the application of the principles for flow control and improve-

Table 1. The conventional and the new production philosophy.

	Conventional production philosophy	New production philosophy
Conceptualization of production	Production consists of conversions (activities); all activities are value-adding	Production consists of conversions and flows; there are value-adding and non-value-adding activities
Focus of control	Cost of activities	Cost, time and value of flows
Focus of improvement	Increase of efficiency by implementing new technology	Elimination or suppression of non-value adding activities, increase of efficiency of value adding activities through continuous improvement and new technology

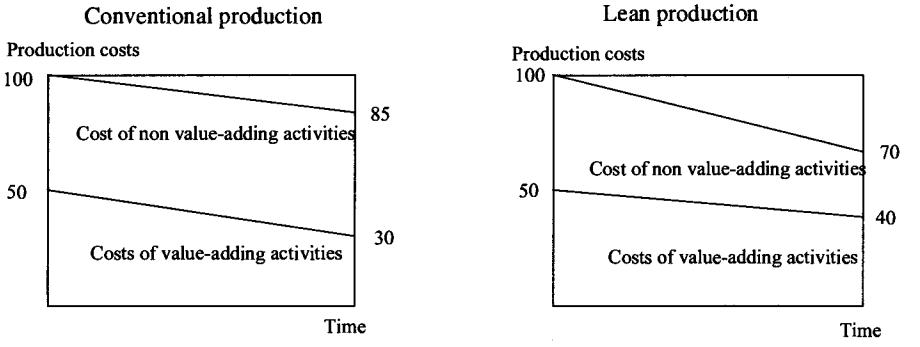

Figure 2. Conventional and lean production: Focus of development efforts.

ment, it is possible to initially reduce the costs of non value-adding activities considerably. Value adding activities are first improved through internal continuous improvement and finetuning of existing machinery. Only after these improvement potentials are realized, major investments in new technology are considered. The implementation of new technology is easier in lean production, because less investments are needed and the production is better controlled. Thus, after the initial phase, increase of efficiency of value adding activities should also be more rapid in lean production than in conventional production.

3 LEAN PRODUCTION IN CONSTRUCTION

3.1 *Preliminary implementation*

In the construction industry, the overall diffusion of the new philosophy seems to be rather limited and its applications incomplete. Quality assurance and TQC have been adopted by a growing number of organizations in construction, first in construction material and component manufacturing, and later in design and construction. The

new approach, in its JIT-oriented form, has been used by component manufacturers, for example in window fabrication and prefabricated housing.

Why has the diffusion of the new production philosophy been so slow in construction? The most important barriers to the implementation of these ideas in construction seem to be the following:

– Cases and concepts commonly presented to teach about and diffuse the new approach have often been specific to certain types of manufacturing, and thus not easy to internalize and generalize from the point of view of construction;
– Relative lack of international competition in construction;
– Lagging response by academic institutions.

However, it seems that these barriers are of a temporary nature. On the other hand, the slow diffusion is not explained by an inadequacy of the new philosophy with respect to construction. This is justified by following analyses of waste and peculiarities in construction.

3.2 *Waste in construction*

To what degree do the problems associated with the conventional production view, as observed in manufacturing, also exist in construction? If the flow aspects in construction have been historically neglected, it logically follows that current construction would demonstrate a significant amount of waste (non value-adding activities). Thus, it is appropriate to check whether the existing information supports this hypothesis.

There has never been any systematic attempt to observe all wastes in a construction process. However, partial studies from various countries can be used to indicate the order of magnitude of non value-adding activities in construction. The compilation presented in Table 2 indicates that a considerable amount of waste exists in construction. However, because conventional measures do not address it, this waste is invisible in total terms, and is considered to be unactionable.

3.3 *Problems of construction are caused by neglect of flows*

Analysis (Koskela 1992a) shows that, as in manufacturing, the conceptual basis of construction engineering and management is conversion or activity oriented. The construction process is seen as a set of activities, each of which is controlled and im-

Table 2. Waste in construction: Compilation of existing data (Koskela 1992a).

Waste	Cost	Country
Quality costs (non-conformance)	12% of total project costs	USA
External quality cost (during facility use)	4% of total project costs	Sweden
Lack of constructability	6-10% of total project cost	USA
Poor materials management	10-12% of labor costs	USA
Excess consumption of materials on site	10% on average	Sweden
Working time used for non-value adding activities on site	Appr. 2/3 of total time	USA
Lack of safety	6% of total project costs	USA

proved as such. Conventional managerial methods, like the sequential method of project realization or the CPM network method, deteriorate flows by violating the principles of flow process design and improvement. They concentrate on conversion activities. The resultant problems in construction tend to compound and self-perpetuate. In project control, fire-fighting current or looming crises consumes management resources and attention so totally that there is little room for planning, let alone improvement activities. As a consequence, there is considerable waste in construction.

3.4 *New conceptualization of construction*

Following the lead of manufacturing, the next task is to reconceptualize construction as flows. The starting point for improving construction is to change the way of thinking, rather than seeking separate solutions to the various problems at hand.

Thus, it is suggested that the information and material flows as well as work flows of design and construction be identified and measured, first in terms of their internal waste (non value-adding activities), duration and output value. For improving these flows, it is a prerequisite that new managerial methods, conducive to flow improvement, are developed and introduced. Such methods have already been developed to varying degrees. Not unexpectedly, they try to implement those flow design and improvement principles which are violated by the respective conventional method. However, lacking a sound theory, these efforts have remained insufficient.

Generally, taking flows as the unit of analysis in construction leads to profound changes of concepts and emphasis.

3.5 *Construction peculiarities*

Construction peculiarities refer especially to following features: one-of-a-kind nature of projects, site production, and temporary multiorganization. Because of its peculiarities, the construction industry is often seen in a class of its own, different from manufacturing. These peculiarities are often presented as reasons when well-established and useful procedures from manufacturing are not implemented in construction.

Indeed, these peculiarities may prevent the attainment of flows as efficient as those in stationary manufacturing. However, the general principles for flow design and improvement apply for construction flows in spite of these peculiarities: *construction flows can be improved.* Consider, for example, the one-of-a-kind nature of construction projects. The same peculiarity is shared by many – if not most – product development projects in manufacturing. However, it has been possible to shorten the development time and to improve the output quality in such projects by implementing principles of the philosophy.

On the other hand, these construction peculiarities can be overcome. Initiatives in several countries, like 'sequential procedure' in France, 'open building system' in the Netherlands and 'new construction mode' in Finland try to avoid or alleviate related problems:

– One-of-a-kind features are reduced through standardization, modular coordination and widened role of contractors and suppliers;

– Difficulties of site production are alleviated through increased prefabrication, temporal decoupling and through specialized or multi-functional teams;

– The number of temporary linkages between organizations is reduced through encouragement of longer term strategic alliances.

However, the *elimination of construction peculiarities is not any solution itself*: It just brings construction to the same level as manufacturing. Unfortunately, a large amount of waste also exists in manufacturing before process improvement efforts begin. Thus, only a starting point for effective process improvement is provided.

Thus it is concluded that the construction peculiarities do not diminish the significance of the new philosophy for this industry.

4 IMPLICATIONS

The implications of the new production philosophy for construction will be far-reaching and broad, as they are in manufacturing. The renewal of manufacturing has been realized in a feverish burst of conceptual and practical development. This might also happen in construction.

4.1 *Implications for academic research*

Current academic research and teaching in construction engineering and management is founded on an obsolete conceptual and intellectual basis. It is urgent that academic research and education address the challenges posed by the new philosophy. The first task is to explain the new philosophy in the context of construction. Formalization of the scientific foundations of construction management and engineering should be a long term goal for research.

4.2 *Implications for major development efforts in construction*

Current development efforts like industrialized construction, computer integrated construction and construction automation have focused primarily on the efficiency of value-adding and to some extent also non value-adding activities. They have to be redefined in order to acknowledge the needs for flow improvement. For example, the following guidelines for construction automation can be derived from the principles presented above (Koskela 1992b):

– Automation should be primarily focused on value-adding activities;

– Construction process improvement should precede automation;

– Continuous improvement should be present in all stages of development and implementation of automation.

4.3 *Implications for the industry*

Every organization in construction already can initially apply the generic principles, techniques and tools of the new production philosophy: defect rates can be reduced, cycle times compressed, and accident rates decreased. Examples of pioneering companies show that substantial, sometimes dramatic improvements are realizable in a

few years after the shift to the new philosophy. Given the presently low degree of penetration, there are ample opportunities for early adopters to gain competitive benefits.

However, for continued progress, new construction specific managerial methods and techniques are needed; presumably they will emerge from practical work, as occurred in manufacturing.

ACKNOWLEDGEMENTS

Reprinted from *Automation and Robotics in Construction X*, 1993, pp 47-54, with kind permission from Elsevier Science, Amsterdam, Netherlands.

REFERENCES

Koskela, L. 1992a. *Application of the New Production Philosophy to Construction.* Technical Report No. 72. Center for Integrated Facility Engineering. Department of Civil Engineering. Stanford University. 75 p.

Koskela, L. 1992b. Process Improvement and Automation in Construction: Opposing or Complementing Approaches? *The 9th International Symposium on Automation and Robotics in Construction, 3 -5 June 1992, Tokyo. Proceedings.* pp. 105-112.

Plossl, G.W. 1991. *Managing in the New World of Manufacturing.* Prentice-Hall, Englewood Cliffs. 189 p.

Schonberger, R.J. 1990. *Building a chain of customers.* The Free Press, New York. 349 p.

Shingo, S. 1988. *Non-stock production.* Productivity Press, Cambridge, Ma. 454 p.

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What do we mean by lean production in construction?*

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1 GENERAL INTRODUCTION

This chapter will discuss lean production in construction. The primary goal of lean production is to avoid waste of time, money, equipment, etc. (Japanese: Muda) (Shingo 1992). Everything is focused on productivity improvement and cost reduction by stimulating all employees.

Koskela (1993) gave an overview of waste in construction. He found results of 6 to 10% of the total project costs in Sweden and the USA.

Investigations in construction companies in the Netherlands (source: INFOCUS Management Consultants) did give the same results. Quick scans gave a result of failure costs (costs to restore failures) of at least 6% of the project costs!

Lean production is a philosophy to decline the waste in production companies. Some elements of this philosophy are used already in construction. We discuss the principles and experiments.

2 BASIC PRINCIPLES OF LEAN PRODUCTION

In fact lean production does not include really new principles of management techniques. It only combines existing principles in a new day. The primary goal of lean production is to avoid waste of time, money, equipment, etc. (Japanese: Muda) (Shingo 1992).

Everything is focused on productivity improvement and cost reduction by simulating all employees. This implicates that everything is done to bring the pain to them who created it. In fact a lot of scheduling and decision problems can be avoided by creating lateral relations between task groups, without managing them in a hierarchical way. Let everybody manage his own problems and don't create new problems by managing the problems of somebody else! Lean production is invented in Japan. Especially the implementation of Toyota is very famous. A wide spectrum of techniques ca be discussed as part of lean production. The most important instruments are:

1. Multifunctional task groups;
2. Simultaneous engineering;
3. Kaizen;

*Presented on the 2nd workshop on lean construction, Santiago, 1994

4. Just-in-time-deliveries;
5. Co-makership;
6. Customer orientation;
7. Information, communication and process structure.

All these aspects can be discussed separately but in fact they have a lot in common. The use of all these instruments together are the basis of lean production concepts. Authors from different fields of management science support the importancy of different techniques. In fact there is no pure lean production concept.

Let's discuss the most important instruments of lean production.

Multifunctional task groups

Many authors agreed that the instrument of multifunctional task-groups is one of the most important instruments of lean production. Instead of homogeneous task groups a multifunctional task groups produce a number of different products. This makes it possible to produce a more complex or more completed product with one production unit. It transfers the maximum number of tasks and responsibilities to those workers actually adding value. In the mean time an accurate response to market developments ca be achieved by flexible deployment of personnel (Womack et al. 1990). In multifunctional task groups workers do not have to wait to each other. It also does not give stocks. To achieve the principle of multifunctional task groups personnel has to be trained intensively in recombining thinking and doing (Kenward 1992).

Simultaneous engineering

Today technology changes rapidly. This reduces the lifecycle of products. For this reason a reduction of product development time is essential. Simultaneous engineering can achieve this. By using simultaneous engineering the design and manufacture of the product are no longer separated, physically and time-wise, but integrated and synchronized, through face to face co-operation between designers and producers in a product development team. Direct communication and co-operation can reduce the development period of products significantly (factor 2 to 3). Simultaneous engineering reduces muda by avoiding miscommunication between engineering and production. Within simultaneous engineering also market research is incorporated. This reduces the development of products which are not liked by the clients.

Kaizen

Kaizen is Japanese for permanent and stepwise quality improvement. Kaizen stimulates personnel at all levels in a company to use their brains to reduce costs. In fact Kaizen requires permanent new ideas for cost reduction. In some cases this implicates a strict demand from the management to all production units to create a new idea each week.

A good implementation of Kaizen implicates cost reduction and zero defects in final products. It is obvious that Kaizen reduces muda (Imai 1993). Kaizen demands employee involvement.

Just-in-time deliveries

Just-in-time is a concept for good-flow control. It stimulates reduction of stocks of material by providing goods when and in the amounts needed (Ohno & Mito 1988).

Traditional good-flow oriented control concepts are managing the stock. Instead, primarily short-term decisions are made based upon the current demand for products. New subassemblies are made only immediately before they are actually needed. The ultimate result is that only extremely small subassembly inventories are needed. Traditional inventory control is based upon detailed scheduling techniques (demand for parts is 'pushed'). With JIT, the actual production of new subassemblies is initiated based upon the demand for products which are really need (the 'pull' approach). Transparent production control (visual management) is important. Stock of materials is seen as muda.

The implementation of JIT needs reliable production (zero defects) and good (and steady) relations with suppliers.

Long term relationships with suppliers (comakership)
The basic idea of comakership is to create co-operation with your suppliers (Womack et al. 1990). This means e.g.:

- Mutual technology transfer;
- Mutual openness;
- Mutual management support;
- Mutual declining of stock;
- Mutual sharing of profits.

Long term relationship with suppliers stimulates a relation which is founded on co-operation instead of conflicts. Disturbances in relations causes muda.

Customer orientation
The entire company must be focused on the client (Womack et al. 1990). Client-supplier-relations are very important internal as well as external. Good communication with your client declines problems. As a result this declines muda.

Information, communication and process structure
Lean production demands a transparent organization (Koeleman 1991). A transparent and flat organization implicates better information and communication, internal as well as external. A simple organization structure makes it easier to communicate. A transparent organization makes is easier to have an overview of consequences of control actions. It is obvious that bad communication declines muda.

3 RESULTS OF EXPERIMENTS WITH INSTRUMENTS OF LEAN PRODUCTION IN CONSTRUCTION IN THE NETHERLANDS

In this section we give an overview of some experiments with instruments of lean production in The Netherlands (Botermans 1994).

Multifunctional task groups
Five years ago some experiments were carried out to use multiskilled gang of workmen in housing. Since the sixties all gang were specialized. A large amount of work was subcontracted. The amount of failures was tremendous, because of the fact that every gang only looked after his own production. The trends of using multi-skilled

gang of workmen were good, but full implementation caused radical changes in organization. One of the consequences was that homes should not finished via a construction project bases at a construction site and using specialized work crews (such as kitchen installers, electricians, plumbers) but rather from a central yard using all-round work crews (Melles & Wamelink 1993). In fact the construction companies did not have the attitude to realize this innovative ideas although the results of the experiments were profitable.

Simultaneous engineering and customer orientation
In fact a lot of engineering activities in construction do have some aspects of simultaneous engineering. During the last years in several design and construct projects simultaneous engineering is used. The results were not always profitable. De Ridder (1994) designed new organization structures for this kind of projects. To implement these ideas a company needs a good system of management procedures. These systems are missing very often. The relation between construction company and client is poor managed (on both sites!).

Kaizen
The first approach to implement Kaizen in construction companies was in the early eighties. The so-called MANS-philosophy (MANS = new style management) created a temporary innovative action. The problem was how to communicate the new ideas in the organization. Another problem was created by the fact that it was difficult to stimulate the employees to improve permanently. MANS died in silence (Melles & Wamelink 1993).

The second attempt was implemented in total quality management. This attempt is still going on but seems to have more success. We will discuss this later.

Just-in-time deliveries and long-term relations with suppliers
Also these experiments (especially in building) were carried out for one project only. A real long-term relationship with suppliers did not exist. All experiments were more or less focused on using detailed delivery schedules. In fact this is in contradiction with the pull-orientation of the JIT-concept.

Information, communication and process structure
During the last years the importance of good and clear information flows is understood. Some research projects were carried out on this subject (Melles & Wamelink 1993). Good communication protocols are impossible if an organization does not have a system of management procedures.

4 APPLICABILITY OF LEAN PRODUCTION IN CONSTRUCTION

The basic idea of lean production is very simple. Keep your production system and production organization simple and avoid waste. Stimulate your employees to improve their own production process. If you want to avoid complex information systems the best way to create good communication within a complex organization is to create bilateral relations between different task groups (e.g. engineering and produc-

tion units) and to give task groups responsibilities (Galbraith 1973). Employees in such an organization have to change their attitude. The management has to create the management frame (what production units do we have, what products do we make, etc.). After that the production units will manage themselves.

In fact the most important goal of lean production is to change the attitude of all employees of a company. In our view Kaizen is the most important instrument of lean production. All other instruments are logical implications of the change in attitude. For example, simultaneous engineering is a logical conclusion of the change in attitude. If we like to make the total production process transparent, if we like to simplify the communication structure, if we like to avoid stock of subassemblies we have to think about the production during engineering activities and reverse about engineering during production.

Up until now most experiments with lean production in construction were focused on implementing one instrument. Most instruments do have overlap with each other instruments, but in fact they can be implemented as stand-alone instruments. For example, it is possible to implement just-in-time deliveries (in a primitive way) on a construction site, without using simultaneous engineering or multifunctional task groups.

Only Kaizen really stimulates all other instruments (including instruments like bench marking which are not mentioned above).

The problem with the Japanese version of Kaizen is that it is developed for the Japanese culture. The mentality of a country and its people is founded in historical events. Neither the Japanese society nor the economic structure of Japan is the same as in Western countries. In Japan the company demands ideas for improvement. Everybody is proud of and loyal to his company and his part of the production process. In fact there is a very emotional relation to the company. In Western countries the attitude to the own company is less emotional.

Kaizen is invented for Japanese companies. This is why Western version of Kaizen has been developed. In fact it is part of total quality management, based on certification according the ISO-9000. Total quality management includes quality assurance and quality improvement. Within the quality assurance manual the system of thinking and acting with quality improvement (Kaizen) has been described. The quality system as well as the implementation can be checked based on the ISO-9000. Such a total quality management philosophy can be externally checked and certified. In the Dutch building industry this seems to give good results. Ten years ago another temptation to implement the basic ideas of Kaizen (MANS-experiment) failed because there was no external check (Melles & Wamelink 1993).

Total quality management is not concerned with only one aspect of the company. It is an integral concept for all units. This makes TQM the integrator of instruments in lean construction. Implementation of TQM based on ISO-9000 is possible in construction companies in Western countries turns out to create a real change in attitude of employees. The real change in attitude can be discovered in general one and a half year after certification (this is 3 to 4 years after the start of the total quality management program!) (source: INFOCUS Management Consultants).

5 CONCLUSIONS AND LESSONS FOR IMPLEMENTATION OF LEAN PRODUCTION IN CONSTRUCTION

In fact the instruments of lean production are not new. The attitude to make it possible to use all these instruments together seems to enforce a real change. If we do not change the attitude of all employees of a construction company we can forget real implementation of lean production. Beside that we need a system of good management procedures to assure good implementation of new ideas. This is the reason why we think that total quality management, based on ISO-9000 is essential to create an environment in which other instruments of lean production can be worked out. If we start with the other instruments they all have a very temporary character.

REFERENCES

Botermans, D.J.M. 1994. *Ook de bouwvakker aan de lijn?* (in Dutch). Catholic University Brabant.

Galbraith, J.R. 1973. *Designing Complex Organizations.* Addison-Wesley Publishing Company, Reading.

Imai, M. 1993. Kaizen, Kaizen.

Kenward, M. 1992. The Fine Art of Mass Production. *New Scientist* 18 July, New York 1992.

Koeleman, H. 1991. *Interne communicatie als managementinstrument. Strategie, middelen, achtergronden* (in Dutch). Bohn Stafleu Van Loghum, Houten/Zaventem.

Koskela, L. 1993. Lean Production in Construction. *Proceedings International Symposium on Automation an Robotics in Construction, Houston* 1993.

Melles, B. & J.W.F. Wamelink 1993. *Production Control in Construction, Different Approaches to Control, Use of Information and Automated Data Processing.* Delft University Press.

Ohno, T. & S. Mito 1988. *Just-in-time for today and tomorrow.* Productivity Press, Cambridge.

Ridder, H.A.J. de 1994. *Design and Construct of Complex Civil Engineering Systems, A new Approach to Organization and Control.* Delft University Press.

Shingo, S. 1988 or 1992. *Non Stock Production.* Productivity Press, Cambridge.

Womack, J.P., D.T. Jones & D. Roos 1990. *The Machine That Changed The World.* Harper Perenial, New York.

Lean production theory: Moving beyond 'can do'*

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1 INTRODUCTION

Lauri Koskela (1992) identified the first task for academics 'is to explain the new philosophy in the context of construction' and this is first objective here. The second is to provide a foundation to understand the contributions of Glenn Ballard which follow. The chapter first discusses changes in the construction industry to suggest why a new (or for that matter any) production theory is required. The extent of the uncertainty experienced on projects leads to yet another comparison between manufacturing and construction. A new understanding of the construction process is offered. Next the concepts of flows and the role of 'lean production theory' (LPT) is examined. The chapter closes with a reflection on the mental models which support current thinking.

One caution, our perspective is drawn from experience in petrochemical and process piping projects. While there appear to be many parallels with experience in other project types, the specific thinking and applications occurred primarily in this industry segment.

2 UNDERSTANDING THE CONSTRUCTION CONTEXT FOR LPT

Significant gains in manufacturing are reported from implementation of LPT in industry. Koskela (1992) identifies the overwhelming dominance of conversion thinking in construction and argues for replacing the conversion model with a flow/conversion model in order to reduce waste. Unfortunately, the foundations of conversion thinking are not clearly explained so its nature must be derived from the tools, techniques, contracts and organizational forms in use. Perhaps the heavy emphasis on the 'critical path method' (CPM) as beginning and ending of planning best exemplifies the conversion theory in practice. Designed for relatively slow, simple and certain projects, these tools, techniques, contracts and organizational forms are inadequate to manage let alone improve practice on quick, complex, and uncertain projects (Laufer et al. unpubl. paper). A trend toward complex, uncertain and quick projects is obvious in the petrochemical business and apparent in other segments.

Competition is becoming intense as constructors try to find new ways to reduce

*Presented on the 2nd workshop on lean construction, Santiago, 1994

costs even as projects become more difficult. Experiments with various forms of TQM, partnering, constructability provide some improvements but no consistent pattern or theory has yet emerged. The development of LPT in manufacturing appears related to changes in the competitive environment which are similar to those being experienced in construction. In construction, as in manufacturing, the changed project environment is the driving force behind the need for new understanding. We should not forget that the impact of LPT in manufacturing extended well beyond the shop floor.

There must be many partial explanations for the persistence of conversion thinking if it is as inadequate as we suggest. Let us offer a few. It is relatively easy to contract for the purchase of a thing and relatively difficult to contract for behaviour (MacNeil 1974). Commercial contract law for the purchase of goods tends to govern the rules applied to construction. Hence we have a continuing focus on contract while projects fail because of lack of teamwork – a behaviour issue.

A second reason may be the apparent efficiency of using a single set of tools for a number of functions. Wouldn't it be wonderful if work could be completely coordinated by a schedule which also provided updated forecasts for senior management, limited claims, and could be broken into smaller plans to direct specific activities? It would be wonderful but no such tool exists – despite the claims of CPM software salesmen. In our experience, it is impossible to show all of the logic constraints with CPM. Further CPM is inadequate in the face of complex resource constraints as Prof. Fondahl himself noted in his early work.

A third set of reasons is suggested by what happens when conversion thinking represented by CPM doesn't work. The typical response in the face of inadequate performance has been to blame the problem on unmotivated or untrained users. To even suggest inadequacy is to provoke strong emotional reactions. After they subside, the problem remains that conversion thinking is inadequate in the face of quick uncertain and complex projects.

Finally, perhaps conversion thinking persists because no adequate alternative has been proposed and the environment of construction projects really has changed, that is, the pressure for completion on uncertain projects has increased dramatically in the last few years.

Current thinking, resting on the needs of a different era, is both unable to deliver significant breakthroughs, and is itself far more damaging than previously understood.

3 THE SITUATION AND ITS IMPLICATIONS

A review of data on the state of uncertainty at the beginning of the construction phase is instructive. Data in Figure 1 shows the state of uncertainty at the beginning of typical construction projects as reported by about 175 project managers representing a broad spectrum of project sizes and types. The data confirms that significant uncertainty is to be expected even as late as the start of construction (Howell & Laufer 1993).

Data in Figure 2 was collected from managers of similar projects. Here the managers reported on their most recent projects as opposed to their 'typical' projects as

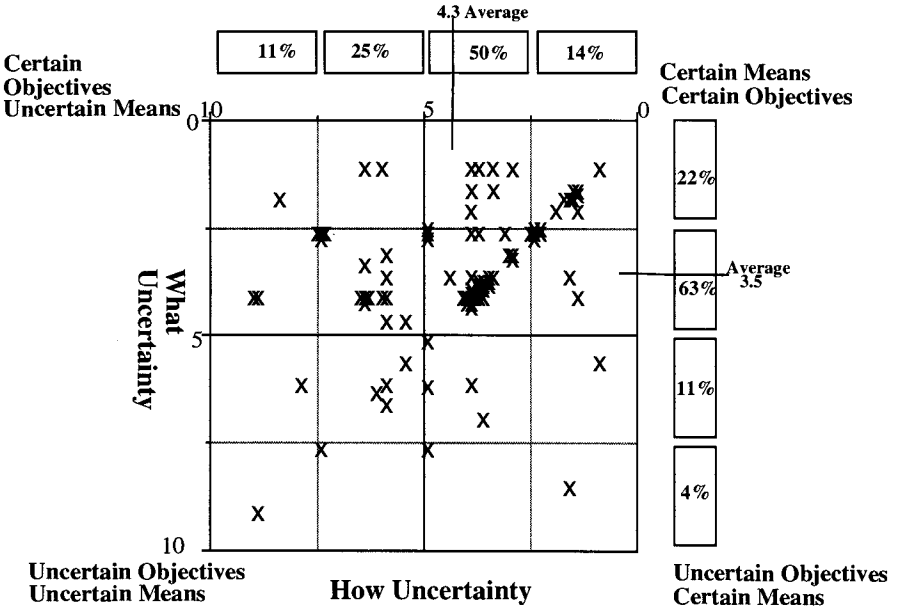

Figure 1. Assessment of uncertainty at the start of construction: Typical projects.

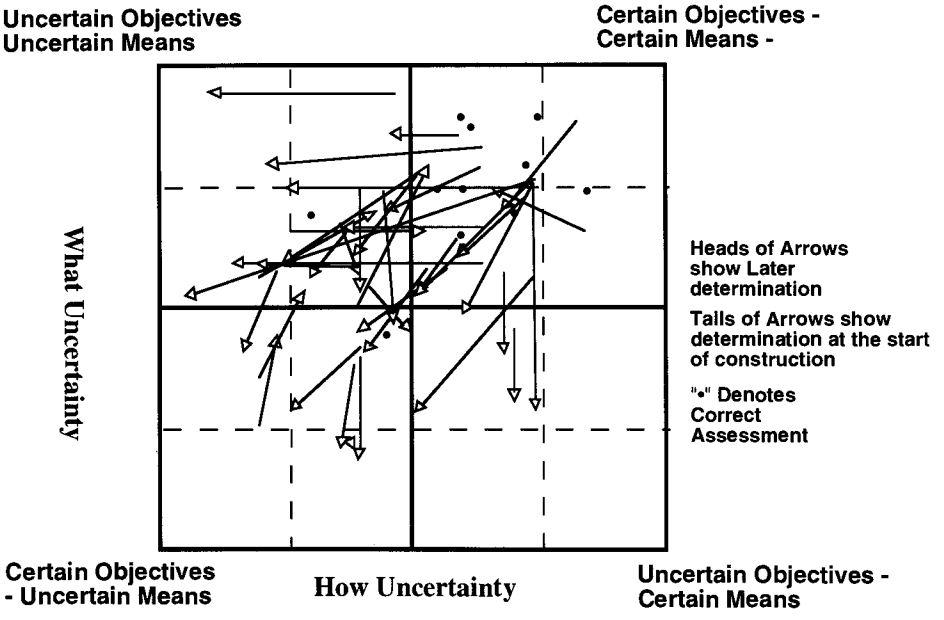

Figure 2. Assessment of uncertainty at the start of construction: Most recent project.

in Figure 1. The managers were asked to use a 'T' to locate where they thought the project was when construction began and an 'R' where it really was once they understood the situation.

This pattern is even more disturbing and compelling. In 85% of the projects, the manager underestimated the extent of uncertainty. The problems they didn't know about were bigger than the problems they knew about.

Consider the waste of proceeding with detailed planning and mobilization on such an unstable basis. If project management accepts real responsibility for project success, the misperception must be rooted in the way planning is conducted. The degree of instability suggests an overwhelming tendency to optimistic evaluations of project circumstance. These evaluations drive managers to plan in greater detail than supported by their information. This persistent optimism suggests either a genetic predisposition on the part of construction planners or a defect in current design of planning systems. Whatever the cause, managers are tending to focus on planning to a fine level of detail far too soon. Focus on technique without an accurate diagnosis of the situation doesn't make much sense. Information must be collected and verified.

In addition to the data on uncertainty, the pressure to reduce project durations is clear. The CII is conducting research in the area and the need for faster completion is widely reported. Recent interviews with superintendents leave little doubt about the increased urgency and complexity of projects in their charge.

LPT in construction must come to grips with the entire design and construction process because increasingly complex projects are being urgently pressed forward under greater uncertainty. Field operations can be improved using LPT principles but even they occur in a different context from manufacturing production. A comparison with manufacturing shows the key feature which distinguishes construction from manufacturing is the extent of uncertainty evident throughout the phase (Table 1).

Table 1. Context of manufacturing and construction production.

	Start of manufacturing production	Start of construction in the field
What	Highly defined	Evolving as means refines ends
How	Highly defined. Operations plan is in great detail based many trials. Primary sequence of major tasks is inflexible, interdependencies are documented and analyzed. Positions in process determine required skills	Partly defined but details un-examined. Extensive planning remains as situation evolves. Primary sequence only partly determined by hard logic but may change. Interdependencies due to conflicting measurements, shared resources, and intermediate products only partly understood. General craft skills to be applied in a variety of positions
Assembly objectives	Produce one of a finite set of objects where the details of what and how are known at the beginning of assembly	Make the only one. The details of what and how are not completely known at the beginning of assembly
Improvement strategy	Rapid learning during the first units preparing for production runs	Rapid learning during both planning and early sub-assembly cycles

In important ways, the life of a construction project is similar to the product development stage in manufacturing. Because a construction project is analogous to the preparation of a prototype, completing the construction phase is better understood as one of the preliminary steps leading to the 'production' which occurs once the facility is completed rather than as manufacturing production exposed to the elements. Reducing uncertainty related to 'what and how' defines the process of 'building a prototype in place'. The challenge for LPT is to reduce waste through bringing stability to the planning process as 'what and how' are refined.

Stability is a key aspect of LPT in manufacturing. There the idea is to minimize input variations so non-value adding steps or flow related activities could be eliminated from the process. Managing flows in construction is more difficult than in the production phase of manufacturing because there is uncertainty both in what is to be accomplished and in the provision of requirements for assembly.

Current construction thinking tends to deny the existence of uncertainty or to suggest it is some sort of moral failure.

– 'If the owner would make up their mind – once and for all, we could do our job.'; or

– 'If the process design engineers would...' and on down the chain.

Once the reality of uncertainty is accepted, a construction project becomes less the transmission of unambiguous orders from the owner to the worker and more a series of negotiations. The object of these negotiations is the rapid reduction of uncertainty. Anything which inhibits these negotiations adds waste. This is true whether the negotiation is between project objectives and means during project definition and design or the more constrained negotiation between shoulds and cans which occurs as foremen prepare weekly work plans.

It is time to examine the concept of flows in relation to the reduction of uncertainty.

4 FLOWS RECONSIDERED

The idea of flows of materials and information from one conversion process to another is quick to grasp. Work in a factory or on a site can be thought of in terms of the movement of materials and information (stuff) through 'input – process – output/input – process – output' chains. Stabilizing work in these chains reduces waste. It requires managing the timing and sequence of the flow of stuff, and assuring it meets downstream requirements.

This simple I/O model is adequate for field assembly operations but is not sufficient for understanding the flows involved in the planning process. Minimizing uncertainty in the flow of decisions and information required in planning is as important as minimizing uncertainty in the flow of stuff. To visualize the flows associated with planning, we propose to expand the horizontal I/O model to include the concepts of directives, i.e. the vertical flow of instructions or standards, the plans for the process at hand. Similar ideas have been expressed by $IDEF_0$ and SanVido but have been thoroughly developed by Talley & Ballard (1990).

In a sense, plans are directives produced by a planning process. They tell the next level what 'should' take place. Inputs such as materials to the work processes de-

termine what 'can' be done. Thus there are two different kinds of flows – one of the plans which become more narrow as the assembly process nears, and stuff which is used in the assembly process. Uncertainty may be transmitted to the work site through either flow. Stabilizing work flow, the subject of Chapter 11 (pp. 101-110), proposes a technique for shielding the workers from uncertainty in both plans and stuff. This is the first step in waste reduction and it provides a basis for further improvements.

Reducing the waste occasioned by the flow of stuff is closely tied to the development of plans. Stable plans both rest on firm upstream assumptions (or premises) and have been tested against the availability of resources. Reducing the variation in the flow of both plans and stuff is the topic of Chapter 10 (pp. 93-100).

LPT, as we understand it, reduces waste by rapidly reducing uncertainty. The implementation strategy is to stabilize work flow by shielding, reduce in-flow variation, then better match labor to available work, and finally improve downstream performance. This strategy both solves problems on projects and clarifies our understanding of LPT. Once this approach is adopted it becomes clear that current management techniques inject uncertainty into the project. Examples will be offered as time permits.

The immediate goal of LPT should be to bring stability to the process by more efficient 'negotiations' between ends and means at every level. Activities such as partnering and constructability which are considered partial implementations of LPT exemplify the negotiation aspect of construction. Important work remains in learning to package and planning to the right level of detail so plans remain in force and stable despite environmental changes. Conversion thinking offers little advice on how to package work so that activities may proceed independently.

5 MOVING BEYOND 'CAN DO'

'Can do' the slogan of the SeaBees of the US Navy summarizes the underlying mental model of most constructors. Ambiguous as it may be, 'can do' is an answer to an assignment. It means, 'no matter what the problem or situation, you can count on me to get the job done.' (no wonder they chose 'can do'.)

A new answer, 'won't do' is possible under LPT because it makes explicit the criteria for decision making. As we develop our understanding of LPT in construction we will confront the underlying thinking of an industry built on 'can do'. Real information on the performance of planning and resource systems can only be available when those charged with planning and doing the work can say 'won't do.' Having the right to say 'no' makes real commitment possible. I am not saying people are allowed to say no on a whim, rather that they are *required* to say no when asked to act beyond the limits of established criteria. This sounds a lot like Ohno's radical decision to allow workers to stop the production lines.

Current management planning and controls systems rely on two unspoken assumptions:

1. The last planner (who you will meet shortly) will always select work in the 'correct' order to achieve project objectives; and

2. Last planners lack the intelligence to manipulate the cost/schedule system for their own short term ends.

In effect we believe they do not know how to protect themselves by selecting the easy work when pressed to increase productivity or production or loose their job.

In short, current management approaches are built on and entice dishonesty. We cannot improve performance unless new thinking exposes the contradictions and weaknesses in our underlying mental models and injects certainty and honesty into the management of projects. It is simple in concept and not hard in execution once we take the challenge of no longer accepting 'can do' when 'won't do' is appropriate. Only then will we have the consistent feedback needed for rapid learning (Senge 1994).

6 WHERE DO WE GO FROM HERE?

Simple, certain and slow jobs hardly pose a challenge. Those best able to manage complex uncertain and quick projects will claim the future. Tools developed to enhance performance on these projects will prove useful on all projects but the aim of LPT should be to help those managing in turbulent situations. Since construction projects are really vast product development processes seldom repeated by the same group of people, and there are so many of these projects, LPT drawn from construction should prove useful across the spectrum of product development efforts.

The idea that LPT ideas drawn from construction could be valuable in other arenas is at first surprising – we tend to think of ourselves as primitive compared to manufacturing. Perhaps our field operations are primitive in comparison with the auto factory of today. This chapter has argued that this is an incorrect comparison. The better comparison is with the product development phase. Here we may not look so bad. It is worth noting that Gilbreth and Ohno, two seminal thinkers in industrial or manufacturing engineering began their careers working in construction.

One caution, we must avoid the tendency (particularly among academics) to deny the nasty uncertainty of the real world. We must avoid the temptation to becoming manufacturing engineers who attempt to change circumstance to fit a theory which is useful in a more stable arena. Rather we must develop our own unique approach to managing all of the flows occasioned by the complex negotiation between ends and means. Once we bring stability to the work environment through better planning, we can turn to the details of methods analysis and there utilize similar principles to those applied at the project level.

REFERENCES

Koskela, L. 1992. *Application of new production theory in construction.* Technical Report No. 72 CIFE, Stanford University.

Howell, G.A. & A.L. Laufer 1993. *Uncertainty and project objectives.* Project Appraisal.

Laufer, A.L., Denker, G. & V. Shenhar (unpubl. paper). *Simultaneous management.*

MacNeil, I.R. 1974. *The many futures of contract.* University of Southern California.

San Vido, V. Various papers in ASCE journals.

Senge, P. 1994. The Fifth Discipline Fieldbook.

Talley, J. & H.G. Ballard 1990. Work Mapping Package.

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Pattern transfer: Process influences on Swedish construction from the automobile industry*

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ABSTRACT: Sweden differs from other Nordic countries in having a large share of manufacturing accounted for by automobile production. In this paper, it is shown that since the 1910s, the process of manufacturing and in particular manufacturing cars has served as a paradigm for process change in Swedish residential and commercial construction. Government policies on construction and joint action by the construction industry have been influenced explicitly by features of the car design, manufacturing and marketing processes. Direct transfer and influence has occurred in contractual relations between owners in the automobile industry and contractors. Over the years, supplier relations or customer relations in the industry have formed patterns for changes in the construction process: Standardization of components for mass production, functional design logic, limited customization, mass marketing and recently EDI links to suppliers.

1 INTRODUCTION

For many years, car makers have been invoked as models for the reengineering of a conservative building industry, perceived to remain stubbornly at a pre-industrial stage and bogged down by obsolete practices inherited from medieval craftsmen. Cars and residences have in common they are about the most costly and durable goods that an average household may consider buying. Both have to fit the human scale, and thus neither can follow very far the path of microminiaturization that has led to such startling increases in productivity and decreases in prices associated with electronics.

But do practices diffuse from car manufacturers to construction contractors? What features migrate, if any, and which are the mechanisms in these cases? The issues to be dealt with here in the Swedish context are mainly two:

1. How is the car industry influence transmitted to the construction industry?
2. Which are the lessons perceived to be learnt from the car industry?

Answers to both these questions have changed over the years.

*Presented on the 3rd workshop on lean construction, Albuquerque, 1995

2 WAYS OF TRANSMISSION

Fundamentally, a number of mechanisms for technology diffusion from car manufacturing to residential and commercial construction can be envisaged:

– A car producer as owner commissions buildings to be produced with construction process changes inspired by its primary production process for vehicles;

– Construction companies search actively for automotive paradigms;

– Government research funds are channelled into industrialization of construction, using car production as a pattern;

– Construction companies recruit white- and blue-collar employees, intentionally or unintentionally, with production experience from the car industry;

– Joint ownership of car related business with construction related business;

– Owners outside the industry point to the automotive paradigm and exert pressure on construction companies to apply practices according to the paradigm.

Sweden differs from other Nordic countries in having car producers within its borders. This raises expectations of direct influences on the Swedish construction sector. Nevertheless, it should be said that although much smaller in terms of population than most other car producing countries, the level of per capita car production is comparable to that of much larger producing countries. Table 1 shows how per capita car production varies over a number of countries. Swedish and US figures for 1990 almost coincide.

3 PARADIGMATIC ASPECTS OF CAR PRODUCTION

3.1 *The Ford model T Era: Standardized mass production*

When Gunnar Asplund and his co-authors, being all the major proponents of architectural modernism in Sweden, published their highly influential 'acceptera' (accept!) in 1931, they pitted the teachings of the (internationally not very widely known) Swedish sociologist Gustaf Steffen against Henry Ford, with Steffen in the role of the observer and with Ford seen as the doer (Asplund et al. 1931).

However, Steffen must be credited with pioneer status, given his analysis more than a decade earlier of how the production methods of industrialism had failed to transform European residential construction, and in particular so in Sweden (Steffen 1918). In his analysis, which he wrote as a member and initiator of the first Swedish Royal Commission on Housing, Steffen noted that only in America would you find factory mass production of components to be assembled – or replaced – for home

Table 1. Car production (per capita) in 1990.

Country	Cars produced per capita
Sweden	0.025
Japan	0.080
USA	0.024
France	0.058

Source: UN Statistics.

construction. With hidden reminiscences of his earlier interest in Ruskin's teachings, he did voice some doubts as to the aesthetic consequences; nevertheless, his plea for prefabrication is clear. His paradigms are not presented in detail and tend to belong to 19th century industrialism: Railroads and steamboats, although there is a sweeping gesture towards 'the whole range of later technical improvements'. Steffen was born in 1864, the year after Henry Ford, and had published his first analysis of industrialism and the Worker Question already in the 1880s.

The 'acceptera' chapter on Industrial Housing Production – Standardization begins with a reflection on the fact that any worker can afford a bicycle. This the authors ascribe to machine work and industrial organization, and they continue to stress that this is the case for most of our commodities, from pins to cars. They refer to the principle of reproduction, implying mass or series production, and find that this necessitates a reduction to a limited number of fixed types, or in other words standardization. Photographs serve to illustrate their concept of types: A Gothic church, a bookshelf, a Doric temple and a 1930s car are reproduced in 'acceptera'.

The impact of standardization on construction activities is expressed by Asplund et al. (1931) as implying a minimization of site work through prefabrication. Variety in construction will be based on a limited number of basic components or types in the market. Photographs from Frankfurt construction are used to illustrate this. When discussing large-scale production, the authors indicate the possibility of using more efficient site equipment for assembly and transports. Not all features are inspired by car manufacturers, it must be allowed: Building components can be manufactured on site using available local materials, they suggest. Teams with interior specialization could be moved from house to house as in the Frankfurt experiment. Identical workers or teams repeat the same work process for each house, which is supposed to lead to an increased work rate and increased precision in the work performed. As to personalization, 'acceptera' takes a dark view of car vendors: 'Or who believes, although the opposite is claimed by smart advertisements, that he for instance can buy a personalized car or a personalized textile for a suit... ?'

At that time, when referring to car production, the immediate Swedish paradigms were probably far less important to the authors than the images transmitted by means of leading foreign modernists, in particular ideologues such as Walter Gropius and le Corbusier. These emphasize a complex of production efficiency and product quality. First, they asserted that they had solved the problem of how to construct residential buildings using a dry method ('la maison *à sec*', le Corbusier 1930) and also that they had acted as the manufacturers of automobiles and railroad rolling stock. Secondly, in 1928, Gropius found a graphical presentation showing price increases in North America since 1913, namely 50% for Ford, 78% for the car industry and 200% for houses, where as the general cost of living had risen to 150% (le Corbusier 1930). This divergent pattern was explained by the perfection of methods of mass production among car manufacturers.

It is not only influences transmitted by thinkers on the European continent which can be traced in 'acceptera', but also models from US sociologists. Since the authors refer to the original Middletown study elsewhere in their book, it is probable that they had been influenced by the heavy criticism levied against the local construction industry in Middletown/Muncie: 'Standardized large-scale production, the new habit in industry that makes Middletown's large automobile parts shops possible, is com-

ing very slowly in the complex of tool-using activities concerned with making house; the building of homes is still largely in the single-unit handicraft stage'. (Lynd & Lynd 1929). Something similar applied to Swedish residential construction at that time.

One of the more influential architects behind 'acceptera', Uno Åhrén, had direct experience from working with the automobile industry just before the book went to press. His responsibility had been the Ford Motor Company assembly and repair factory in the Free Port of Stockholm, built in 1930/1931 and considered a breakthrough project in Sweden. Brunnberg (1990) in her study of the industry architecture of modernism in Sweden points out the influence of Ford's chief architect through many years, Albert Kahn, and his floor layouts and innovative use of new materials in the service of car production.

3.2 *The BMC 1000 Era: Product development*

The principles of mass production as advocated in the 1930s would not be applied extensively to residential production in Sweden until the 1960s, when the annual volume went up rapidly. Although high-rise apartment buildings construction with large prefabricates stood for a smaller proportion after the early 1960s, in 1965, the decennial million programme was declared by the government, based on support for mass production. The objective of one million new homes was met, but criticism of stereotyped environments produced grew more vocal. Could monotony be broken, and would the car manufacturers provide another paradigm?

The Swedish Industries' Building Study Group (1969) used an innovations study published by the Royal Swedish Academy of Engineering Sciences two years earlier where 'the British car BMC 1000 is used to exemplify active, product-yielding research and development work'. The example shows how systematic development work based on well-known techniques results in better products being offered to the consumers. Also underlined was how R&D leads to results when transformed through product development into successful products, and 'the decisive part played by companies as regards development and progress'. One consequence was emphasis on functional design logic and pressure on the formulation of building codes so that performance requirements would be used more frequently, leaving room for product innovation in the construction industry.

3.3 *Quality assurance: Volvo as customer*

The type of industrial thinking represented by the million programme was seldom focused on details of product quality or on responsiveness to owner and user needs. Rising maintenance costs and owner dissatisfaction were often discussed but with no obvious solution. The Volvo Group Headquarters outside Gothenburg (Petersson 1984) was however a fresh initiative. Here, the largest car manufacturer in Sweden required that the contractor should present a system for quality assurance. Although there were precedents in the construction of nuclear energy plants during the 1960s, no contractor had any other experience of quality assurance systems. Interesting is that the owner (Volvo) was unwilling to impose on contractors its then current quality systems for suppliers of car parts. Instead, when pressed by contractors, Volvo re-

frained, and as a consequence, the successful contractor, F.O. Peterson, had recourse to the at that time unique Canadian standard for quality assurance and had to adapt this standard independently to construction purposes (Augustsson 1995).

3.4 *Electronic data interchange: SAAB and suppliers*

Interest in and the introduction of Electronic Data Interchange (EDI) in the Swedish construction sector have clearly been influenced by the relations between suppliers and producers in the car industry. The fact that SAAB requires suppliers to communicate through the medium of ODETTE has been important.

4 FROM MASS TO LEAN PRODUCTION: CURRENT VIEWS

4.1 *Remnants of the mass production paradigm*

The traditional interest in the mass production paradigm is still alive. Johansson & Snickars (1992) mention development phases and periods of change in the automobile industry, starting with the analysis performed by Altshuler and others published in the MIT 1984 report on the Future of the Automobile. Johansson & Snickars (1992) claim that the Swedish construction industry had developed up to 1950 to the point where automobile production found itself before the Ford model T Era, i.e. before 1910-1920. It is especially economies of scale and the advent of mass production in housing during the 1960s that Johansson & Snickars (1992) discuss.

Supply chain coordination is an issue which includes both the old concern with prefabrication and other aspects. In the 1994 PEAB Annual Report, the CEO of one of the largest contractors in Sweden says 'Volvo or SAAB would hardly buy e.g. pipes in ten metre lengths to be cut and bent so that they fit the car. But that is the way we work on a construction site'. Such observations remain commonplace and are basically along the lines of the reasoning first formulated earlier in the century.

4.2 *Focus on time*

It is only with the 1990s that the focus on time as a metric for production arrives in the construction sector, first as part of the Skanska 3T program (Ekstedt & Wirdenius 1994; Bröchner 1994). Here, the lag between acceptance of time focus in the manufacturing industry and in construction is minimal. The theme is often repeated during the first half of the 1990s: Redtzer (1994) refers to the automotive industry and its manufacturing of components and systems to cut construction times by half, which would give at least 20% lower construction costs.

4.3 *Personalized products*

More surprising is the claim that the present car industry provides greater scope for personalization of products than does construction. A recent trade magazine article (Redlund 1995) on future residential construction starts by noting that the car industry delivers its products with specialized details and equipment, according to the

wishes of the individual customer, and then ventures to ask whether future homes can be preordered in a similar way and adapted to the needs of the resident. This is very far from 'acceptera' in 1931, when car producers were seen as paradigmatically uninterested in individual whims.

4.4 *Learning from lean production: Arcona AB*

The construction management activities of Arcona AB are of special interest because they were until recently carried on in parallel with another company in the group being agent for German and Japanese cars in Sweden. However, with the possible exception of the Nissan transplant factory in Sunderland, UK, top Arcona managers are reluctant to identify direct influences from the car industry on their methods for construction management (Birke & Jonsson 1995). As external sources of ideas in addition to the car industry, Arcona does acknowledge the ABB Group and its T50 program for reducing cycle times by half. Effects of the T50 program are spread by ABB subsidiaries in their role as suppliers to firms such as Arcona. T50 is important for its customer orientation and its hunt for time. Another source of inspiration is producers of luxury yachts, where just-in-time procedures are based on traditional craftsmanship, well organized traditional craft work being appreciated as a form of lean production. However, the main source of inspiration is claimed to be the day-to-day activities and experiences in construction projects.

For Arcona, focus on time has been the main principle, discovered as the key to rational production. Process orientation has been seen as essential, implying that non-value-adding activities should be squeezed out. There should be raised precision in all that is done, so as to minimize surprises. This means using the best competence available and dependable partners as strategic suppliers, who should participate from the outset. In this manner, the basis for continuous change is laid, including technology change. Everything should be subordinated to relations so as to escape from the traditional division into opposite parties being kept apart by strict boundaries. In short, all firms involved should profit from being less costly in the process. Ideally, there should be incentive agreements tied to all interfirm relations. According to the 'less of everything' principle, small organizations in a small concentrated core group which (*pace* IT) should sit together in the literal physical sense is desirable; also that this organization is retained from project to project, again with as few people as possible being involved. 'If people always do right, fewer people will be needed'.

5 CONCLUSIONS

In spite of the frequency with which car manufacturing has been invoked as a paradigm for construction, there have only been a few clear-cut cases of direct transfer of ideas and work practices from the car side, and then only when a car manufacturer such as Ford or Volvo has acted as customer to the construction industry. Perhaps the more efficient ways to influence construction has been through the medium of gen eral interest in foreign cultures of manufacturing, historically appearing on the scene in the order of US and Japanese influences on the Swedish industrial imagination. To take only the two most prominent, focus on time and on stronger relations with key

suppliers are transforming all branches of industry and consequently also how large contractors choose to operate. The time lag between the rest of industry and construction is not long nowadays; the slowness to conform has probably to be explained by peculiarities in the IT support for most types of construction activities.

REFERENCES

Asplund, G., Gahn, W., Markelius, S., Paulsson, G., Sundahl, E. & Åhrén, U. 1931. *Acceptera* (Accept, in Swedish). Stockholm: Tiden.

Augustsson, R. 1995. Personal communication.

Birke, H. & Jonsson, J.E. 1995. Personal communication.

Brunnström, L. 1990. *Den rationella fabriken* (The rational factory, in Swedish). Umeå: Dokuma.

Bröchner, J. 1994. Organizational adaptations to strategic developments in construction companies. *Proceedings of the A.J. Etkin International Seminar on Strategic Planning in Construction Companies, Haifa, 8-9 juni 1994*, pp. 35-49. Haifa: National Building Institute, Technion.

Corbusier le, E.J. 1930. Analyse des éléments fondamentaux du problème de la 'maison minimum' (Analysis of fundamentals of the Minimal Home Problem, in French). In: *Die Wohnung für das Existenzminimum*, pp. 20-29. Frankfurt: Englert & Schlosser.

Ekstedt, E. & Wirdenius, H. 1994. Enterprise renewal efforts and receiver competence: The ABB T50 and the Skanska 3T cases compared. Paper presented at the IRNOP Conference, Lycksele, Sweden, March 22-25.

Gropius, W. 1924. Wohnhaus-Industrie: Ein Versuchshaus des Bauhauses (Residential industry: An experimental Bauhaus house, in German). *Bauhausbücher*, Vol. 3. Munich: Albert Langen. (Tr. in Scope of Total Architecture. New York: Harper & Brothers 1955).

Johansson, B. & Snickars, F. 1992. *Infrastruktur: byggsektorn i kunskapssamhället* (Infrastructure: the construction sector in the Knowledge Society, in Swedish). The Swedish Council for Building Research, T33:1992. Stockholm.

Lynd, R.S. & Lynd, H.M. 1929. *Middletown: A Study in Contemporary American Culture*. New York: Harcourt, Brace & Co.

PEAB Årsredovisning 1994. (Annual Report) (p. 6).

Petersson, C.-G. 1984. Volvo HK ett pilotprojekt för kvalitetssäkring (Volvo HQ, a pilot project for quality assurance, in Swedish). *Byggmästaren*, No. 5, pp. 37-38.

Redlund, M. 1995. Framtidens bostäder kräver trendnissar (Future homes need trendies, in Swedish). *Byggindustrin*, No. 19, pp. 26-28.

Redtzer, U. 1994. Vi bygger dyrt med förlegade metoder (We build expensively with obsolete methods, in Swedish). *Dagens industri*, February 1.

Steffen, G. 1918. *Bostadsfrågan i Sverige* (The Housing Question in Sweden, in Swedish). Bostadskommissionens utredningar, Vol. IX. Stockholm.

The Swedish Industries' Building Study Group 1969. *The New Building Market: Product Responsibility, Competition, Continuity*. Stockholm: Byggförlaget.

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The knowledge process*

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ABSTRACT: This chapter describes the knowledge process and how it is a part of lean construction principles. The knowledge process is then further viewed within the context of two current research projects being conducted by the department of civil engineering at the University of New Mexico. One research project, funded by the National Cooperative Highway Research Program (NCHRP), is entitled 'Constructibility review process for transportation facilities,' whose purpose is to develop a formalized constructibility review process for state highway agencies. The other research program, sponsored by the Construction Industry Institute (CII), is entitled 'Modeling the lessons learned process,' and has as its purpose to develop a formalized lessons learned process for CII member companies to follow, in order to implement knowledge. Both of these research projects are viewed in the broader context of knowledge management and current organizational learning theory as it applies to lean construction.

1 INTRODUCTION

Before I begin this chapter, I must first defend my basic premise that the knowledge process is part of lean construction. Knowing that the definition of lean construction is still being argued, this becomes no less a challenge. If you use Womack's definition of *lean production* as a starting point for the definition of *lean construction*, then the principles would be (Womack 1990):

- Teamwork;
- Communication;
- Efficient use of resources;
- Elimination of waste;
- Continuous improvement.

Certainly the learning organization demonstrates these abilities, regardless of whether you are in a production organization (i.e. manufacturing) or a project organization (i.e. construction). Senge refers further to learning organizations and the 'disciplines of theory, methods, and tools representing bodies of actionable knowledge (Senge 1994)'. Both of these authors substantiate the importance of knowledge and learning as an important aspect of lean production and therefore of lean construction.

*Presented on the 3rd workshop on lean construction, Albuquerque, 1995

It is a commonly known fact that we have entered the age of information. In fact, one could say, to quote vice president Al Gore, that we are in the age of 'exformation' because of the deluge of knowledge that is available to all on internal, corporate computer networks, as well as externally on the world wide web. Peter Drucker (1994), writing in The Atlantic Monthly, describes a social transformation that is dramatically changing the socioeconomic makeup of the United States as the 'rise of the knowledge worker'. This worker will need both formal education and a habit of continuous learning (Drucker 1994). Corporations are finding that they must incorporate both continuous improvement and organizational learning in order to improve business results and compete in a global economy (Gupta & Fisher 1994).

2 CONSTRUCTIBILITY REVIEW PROCESS

Constructibility is defined by CII as 'the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives (CII 1986)'. The use of the word 'knowledge' implies that it can be thought of as is a subset of a body of knowledge acquired during the construction phase of a project. This could include both knowledge that has been collected historically with experience, or current new knowledge being acquired and demonstrated in the form of best practices.

The NCHRP has funded a research project with the purpose of developing a formalized constructibility review process (CRP) for the state highway agencies to utilize, in order to implement constructibility into their project development processes (PDP's). In this research project, a tool similar to business process reengineering (BPR) was utilised to model the CRP. The specific process modeler that was used was IDEF0, a modeling technique that was developed originally by the US Air Force. This technique formalizes a process by identifying the primary functions of the process and including, inputs, outputs, constraints and resources associated with each function (see Fig. 1).

As with any process modeler, the intent is to model the process as it now occurs (known as the 'as is' process) and then to reengineer that process in the form of a 'would be' model, attempting to improve the process by eliminating non-value added functions. This is a basic premise of the new production philosophy (Koskela 1992). The only problem with applying this technique to this project was that an 'as is' CRP was non-existent for transportation agencies. In a survey of all 50 state transportation agencies, it was discovered that only 23% of the agencies had a formalized CRP process, and upon further investigation of these 'formal' processes, the definition of 'formal' was found to be quite subjective. Most of these 'formal' processes lacked distinct functions or steps that lead the user through the implementation process (Anderson & Fisher 1994). This is not surprising, since CII stated that the number one barrier to constructibility was the perception that companies were already doing that (CII 1993). Therefore, the researchers superimposed the CRP over the standard transportation agency project development process (PDP) as the solution to process modeling (see Fig. 2).

As a result of modeling, a useful, formalized CRP process resulted that is cur-

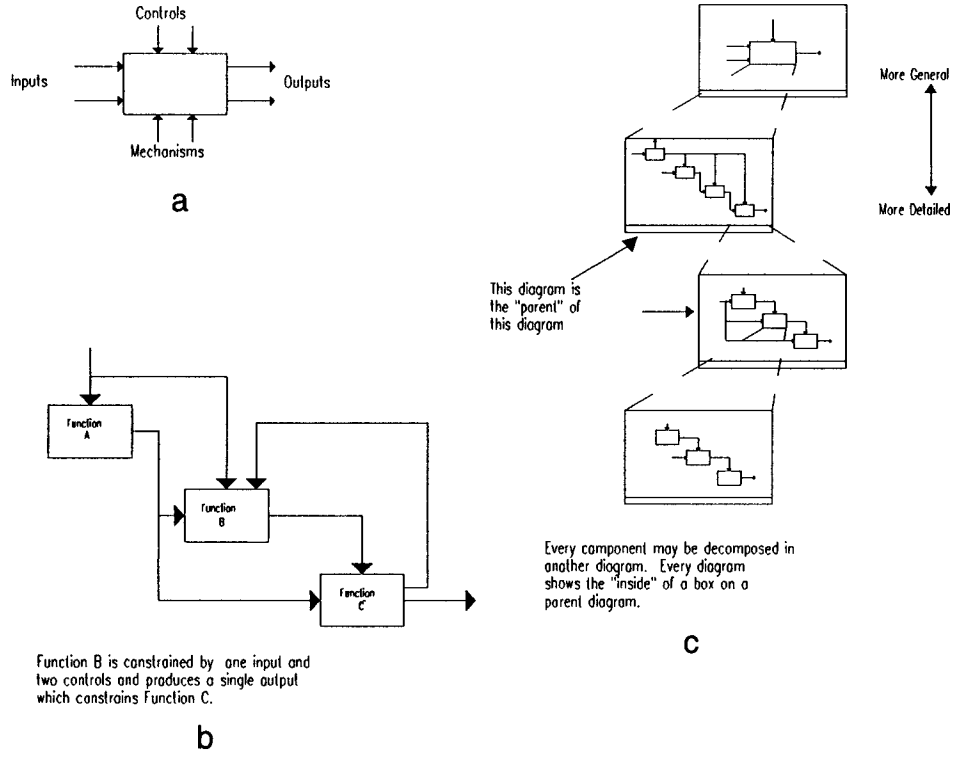

Figure 1. IDEFO function modelling: a) Function box and interface arrows, b) IDEFO model structure, c) Constraint diagram.

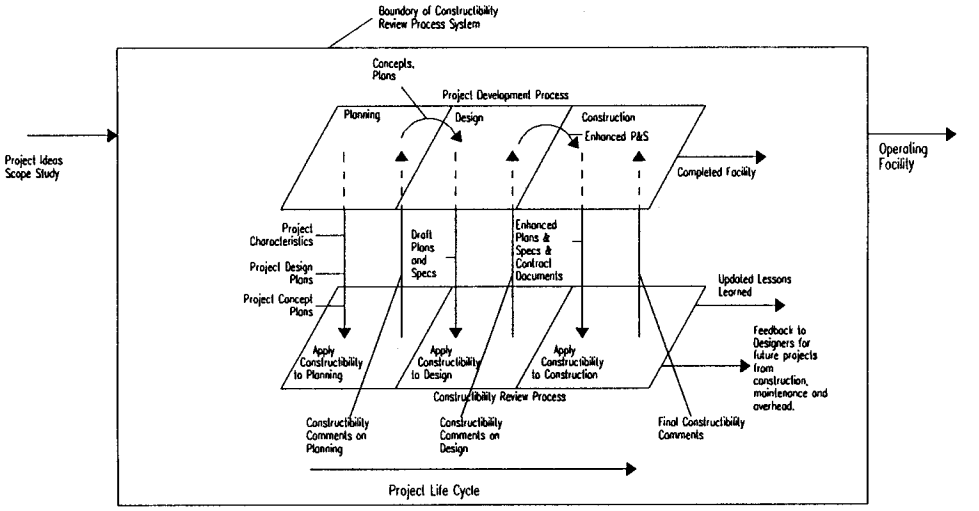

Figure 2. Linking constructibility functions to project development process.

rently being structured into the form of a workbook to train state transportation agencies on how to implement constructibility into their standard PDP's. However, perhaps more insight was gained by the researchers in identifying certain paradigm shifts encompass lean construction principles. Paradigm shifts resulting from this research were (Anderson & Fisher 1994):

- Existence of agency policy for constructibility;
- Use of project constructibility processes for design and construction;
- Contract strategy;
- Use of a constructibility consultant/engineer;
- Use of lessons learned;
- Use of constructibility implementation tools;
- Use of constructibility team;
- Enhancement of plans and specifications and contract documents;
- Feedback from maintenance and operations.

Even though it was beyond the scope of this project, these paradigm shifts indicated that we began to look outside of the project boundaries and see the importance of organizational culture and what changes are necessary for learning to take place.

3 MODELING THE LESSONS LEARNED PROCESS

The construction industry struggles with its ability to capture the 'lessons learned' from its projects and activities for the benefit of future, similar work. Very often, the knowledge gained on a particular project is lost with the changing or leaving of the people who worked on the project. This problem occurs throughout project execution, but often is most evident during the later phases (i.e. construction and operations) when design is well complete. Owners and contractors must depend on job end reports and/or rapid communication to transfer lessons learned from project to project. In today's fasttrack project environment, this is virtually impossible without a formal, systematic process that is to some extent automated. For these reasons, CII has just begun a research effort this year to develop a lessons learned model for use by its member companies, in order to implement lessons learned into the earlier phases of a project so that mistakes are not repeated from project to project. This model should increase the widespread use of lessons learned from previous projects as a tool for continuous improvement.

In an initial survey, 45% of CII member companies state that they have a formalized lessons learned process. As with the NCHRP project, we are in the process of investigating these 'formal' existing processes, as well as identifying other best practices, such as the Martin Marietta model illustrated in Figure 3a and 3b (Sidell 1993). We have learned, so far, that most companies are using some form of knowledge sharing, such as Lotus Notes or the World Wide Web. We anticipate that some hybrid formal process will be developed as a result of this research project for dessemination to CII member companies.

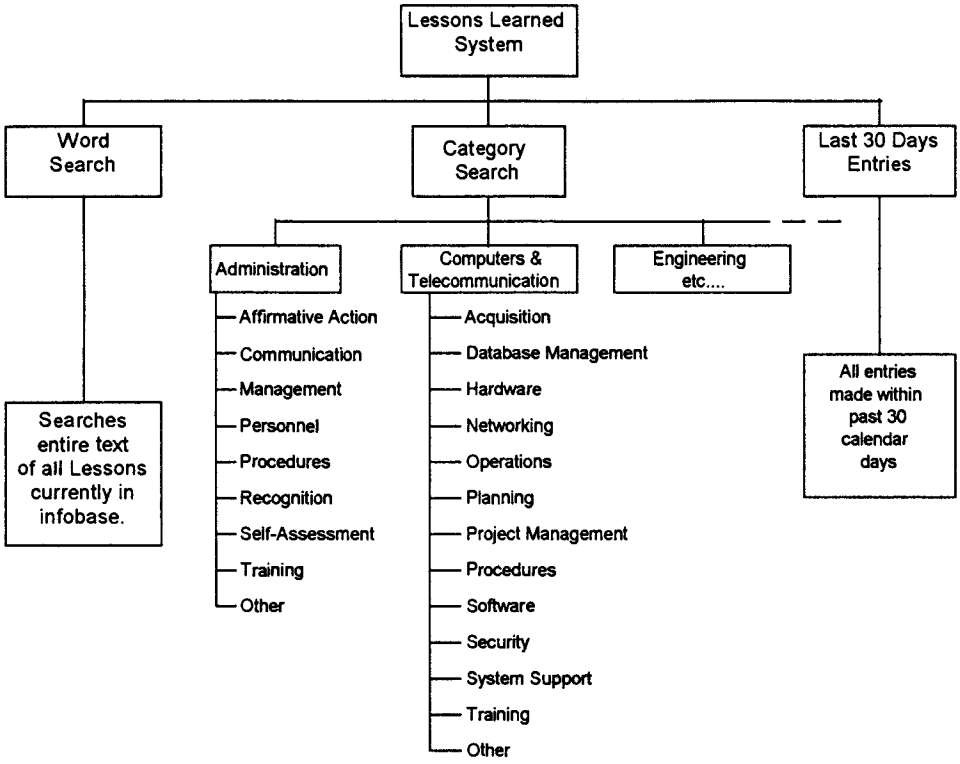

Figure 3a. Lessons learned organization.

4 ISSUES IN KNOWLEDGE MANAGEMENT

If you view the knowledge process as containing the three areas illustrated in Figure 4, you will see that at the centre of the process is the knowledge itself, that is contained within the knowledge management process of collecting, analyzing, and implementing this knowledge into some sort of form or process that the organization can use. At the recent Knowledge Imperative Symposium in Houston, TX, sponsored by Arthur Anderson and the American Productivity and Quality Centre, we learned that these two inner circles only represent about 10 to 20% of the knowledge process. By far, the more difficult issue to address, and the one with far greater potential, is the outer circle of this figure, that is to say the organizational learning culture. Perhaps this is because of what Senge says 'the organization continually becomes more aware of its underlying knowledge base – particularly the store of tacit, unarticulated knowledge in the hearts and minds of employees (Senge 1994)'.

So if at the heart of lean construction is the management of the knowledge process, what solutions can be applied to research projects at UNM, in order to make the types of improvements in construction that Womack (1990) espouses in lean manufacturing? Solutions are found in the following issues, summarized from the recent knowledge symposium that address how to implement the knowledge process into

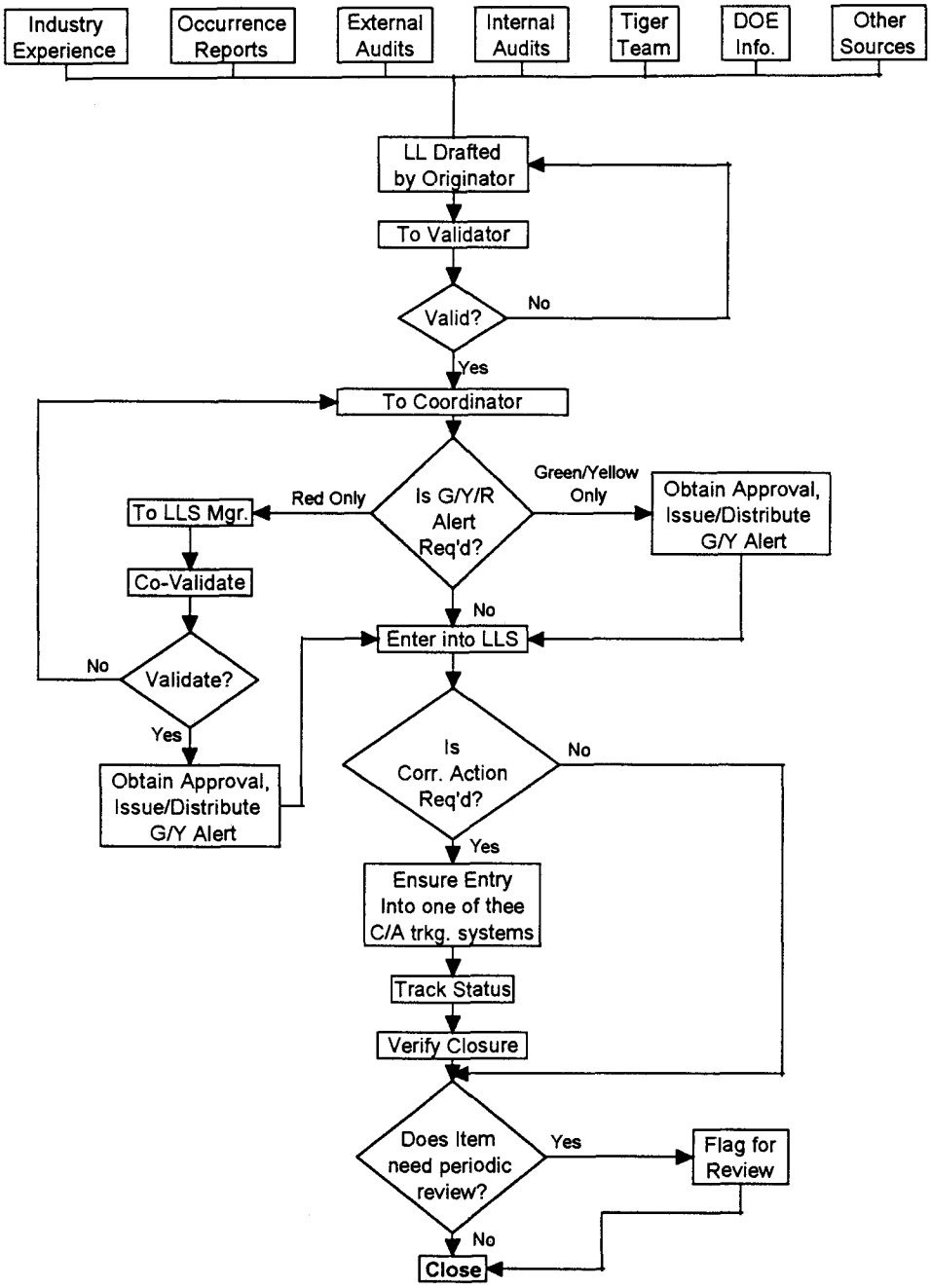

Figure 3b. Lessons learned system flow.